

Publications

BULLETIN
OF THE
UNIVERSITY OF TEXAS

1915: No. 17

MARCH 20

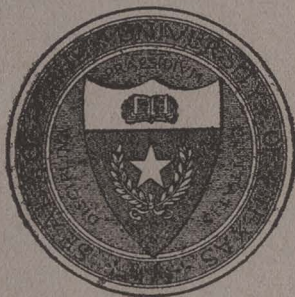
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Bureau of Economic Geology and Technology
WM. B. PHILLIPS, Director

Potash in the Texas Permian

by

J. A. Udden



Published by the University of Texas
AUSTIN, TEXAS

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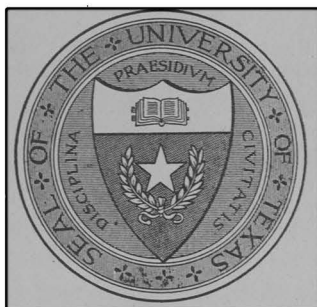
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The Mineral Resources of Texas. Wm. B. Phillips. Issued by the State Department of Agriculture as its Bulletin No. 14, July-August, 1910. (Out of print).

The Composition of Texas Coals and Lignites and the Use of Producer Gas in Texas. Wm. B. Phillips, S. H. Worrell and Drury McN. Phillips. University of Texas Bulletin No. 189, July, 1911. (Out of print).

A Reconnaissance Report on the Geology of the Oil and Gas Fields of Wichita and Clay Counties. J. A. Udden, assisted by Drury McN. Phillips. University of Texas Bulletin No. 246, September, 1912.

A Map Showing the Location of Iron Ore Deposits in East Texas; Blast Furnaces; Lignite Mines in Operation; Lignite Outcrops; Producing Oil Fields, etc. Wm. B. Phillips, September, 1912. (Out of print).

Eighteen Press Letters, dealing with various features of mineral production in Texas. (Out of print).

The Fuels Used in Texas. Wm. B. Phillips and S. H. Worrell. University of Texas Bulletin No. 307, December 22, 1913.

The Deep Boring at Spur. J. A. Udden. University of Texas Bulletin No. 363, October 5, 1914. (Out of print).

The Mineral Resources of Texas, by counties. Bull. 365 (in press).

Address all communications to

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PREFATORY NOTE.

By Wm. B. Phillips, Director.

During the last two or three years, this Bureau has examined a large number of samples, from different parts of the State, for potash. Excluding the isolated and commercially valueless deposits of nitrate of potash, described in a paper entitled "Investigation of Sources of Potash in Texas," published in Bulletin No. 98 of the American Institute of Mining Engineers, February, 1915, the present Bulletin and Bulletin No. 363 on The Deep Boring at Spur, of the Bureau, contain practically all of the definite information we now have concerning the existence of possibly workable beds of potash salts in Texas. The studies of the deep explorations here presented were made by Dr. J. A. Udden, geologist of the Bureau. The chemical analyses were made by Mr. J. E. Stullken, chemist of the Bureau. The commercial importance of the matter is well illustrated by the fact that during the five years ending with 1913, we imported into this country nearly \$50,000,000 worth of potash salts from Germany, the sole source of supply. Taking one year with another, the annual value of our imports of potash salts is close to \$10,000,000.

These importations have practically ceased and it is wholly uncertain when they can be renewed. The European war has completely unsettled this business.

Much before the beginning of this war, the United States Department of Agriculture and the United States Geological Survey had conducted extensive investigations, chiefly in Nevada, California, etc., with the hope of finding domestic sources of potash salts. Near the center of Carson Sink, Nevada, the United States Geological Survey sank a well to the depth of 985 feet, in the search for these salts.

It is not the purpose of this Introduction to review the matter of the search for potash salts in the United States during the last few years, but it is thought that some comparative figures might be given with reference to the discoveries elsewhere than in Texas.

Natural brines from Death Valley, California, have shown a maximum amount of potash (K_2O) of 3.43 per cent. in the

total salts, which comprised about 28 per cent. of the original sample. This amount was found in the ground water in the salt crust at the "sink."

In brines from the Saline Valley, California, the maximum amount of potash found was 1.56 per cent. In wells bored at Columbus Marsh, Nevada, the maximum amount of potash found was 25.18 per cent., expressed as percentage of the soluble portion of the sample, which was 6.30 per cent. of the original sample. This sample came from a depth of 27 feet. The borings at this place reached a maximum depth of 50 feet and the amount of potash found varied from 0.41 to 25.18 per cent. In saline residues from the drainage basin of Railroad Valley, Nevada, the amount of potash found, expressed as percentage of the soluble portion, varied from 0.89 to 12.19, the soluble portion in the first case being 25.24, and in the latter case, 55.20 per cent. of the original sample.

A sample of mud taken four feet below the surface of Jesse Lake, in western Nebraska, gave 28.92 per cent. of potash, expressed as percentage of the soluble portion, which was 4.63 per cent. of the original sample.

The highest percentage of potash in brines that has been noted in the preparation of this Introduction was 35.85, from a pond on the Star ranch, western Nebraska. In this case, however, the dissolved salts comprised only 3.21 per cent. of the original sample.

These references are from Bulletin No. 540, Part I, United States Geological Survey, 1914.

Searles Lake, in southeastern California, which appears to be an exceptionally favorable locality for potash salts, is described in Bulletin No. 580-L, of the United States Geological Survey, 1914.

There are two especially important features in the discovery of potash salts in Texas, which this Bulletin announces. The first of these is the discovery of potash-bearing "salt" in depth and the other is the extent of the area in which this "salt" occurs. The potash-bearing material is not a brine, but a solid. One of the wells is in Potter County, 23 miles northwest of Amarillo; the other one is in Randall County, 16 miles south and west of Amarillo. The distance between these two wells

is about 30 miles in a southeast direction, the well in Randall County being about 18 miles farther east than the Potter County well.

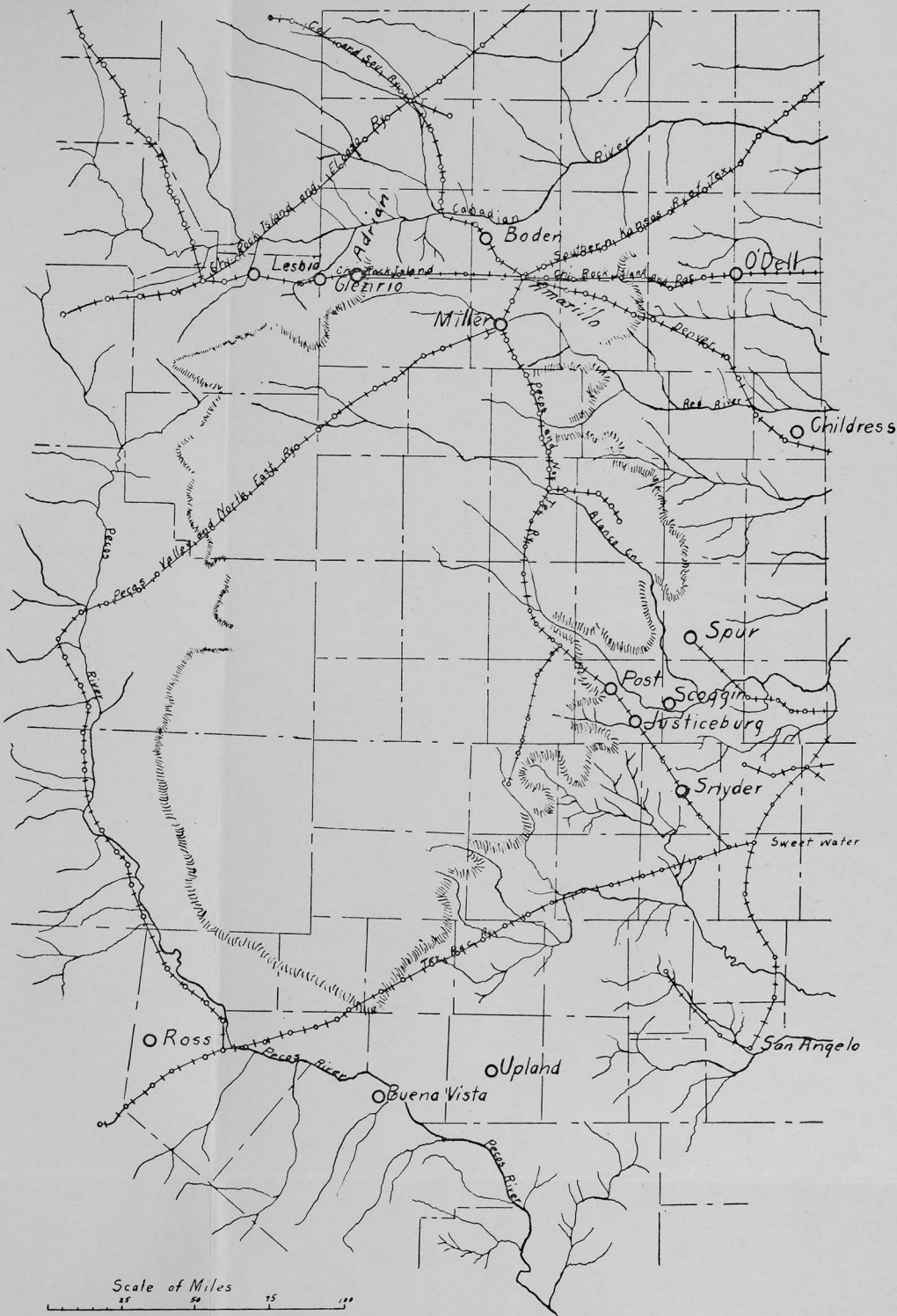
In the Potter County well, the highest amount of potash found, expressed as percentage of the soluble portion, was 9.23, from a depth of 875-925 feet. The soluble portion in this case was 87.24 per cent. of the original sample.

In the Randall County well the highest amount of potash found, expressed as percentage of the soluble portion, was 10.50, from a depth of 1700 feet. The soluble portion in this case was 51.72 per cent. of the original sample.

In concluding his observations, Dr. Udden says: "...the territory which appears from our present knowledge to give most promise is along the supposed axis of the basin, southward and a little westward from Boden, the Miller well and Adrian. From the sections already made, it is evident that tests should extend to the greatest depth at which it may be considered profitable to work, say, 2000 feet. The 'red salt' horizon in the Miller and the Boden borings will lie, it is believed, over most of the territory indicated, between 2000 and 2400 feet above sea-level, or from 800 to 1700 feet below the surface."

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INTRODUCTORY.

In an earlier publication* an account was given of the discovery of potash in a brine from the deep well at Spur, at the depth of about 2200 feet. The quantity amounted to 5.4 per cent. of potassium chloride in the total soluble solids, in one sample. After the publication of this report, the Bureau of Economic Geology and Technology of the University of Texas received samples of drillings from several other explorations in the western part of the state. Some of these drillings contained fragments of rock salt. Several samples of this rock salt have been analyzed and found to contain considerable quantities of potash. In two cases, it is believed that a potash mineral, such as carnallite, has been found. This is a bright salmon red substance containing about 14 per cent. of potassium chloride. It came, in one case, from a depth of about 900 feet below the surface, in a sample representing a fifty-foot bed of rock salt. This salt overlies three other salt beds, measuring jointly several hundred feet in thickness. In the other case, it was found in some rock salt coming from a depth somewhere between 1500 and 1700 feet. It is believed that this occurrence of potash in the form of a native mineral in association with salt deposits in the Permian redbeds at a moderate depth, warrants further explorations. In order that such explorations may be made as intelligently as possible, I wish to review some information which has been collected during the last three years and has a bearing on the geology of the Panhandle and the adjacent country, with special reference to the possible occurrence of workable potash deposits in these beds.

Data From Borings.

The data secured consist of drill records and in some cases the determinations of contents of samples of cuttings from eighteen borings in the area of the Permian redbeds. The locations of these borings are shown in Figure 1. Ten of these borings extend in a belt from a little south of east, to north of west, across the north part of the Plains, following the drain-

*The Deep Boring at Spur, by J. A. Udden, Bull. of Univ. of Texas, No. 363.

age of Red River. The formations explored in these borings are shown in Figure 1. The other borings are located in a belt which is peripheral to the south end of the Llano Estacado, from Dickens county on the north, then south, southwest, and west, to Reeves county, west of the Pecos. The formations in these borings are shown in Figure 2. The data from which these sections were made are presented below.

Lesbia, New Mexico, Boring.

At Lesbia, New Mexico, a boring has recently been made for oil, 1414 feet deep, on land belonging to Mr. J. W. Lowing. Mr. Lowing furnishes the information that the first 1200 feet were in rock (probably mostly shale and sandstone). Below this depth, there was a bed of 100 feet of salt, followed by more rock, which was sufficiently indurated to be taken out in cores three feet long. Information from another source was to the effect that some salt had been penetrated at about 700 feet below the surface. This boring is on the east side of Arroyo Plaza, in the Triassic. Elevation of curb, estimated: 3950 feet above sea level.

The Glenrio Well.

Driller's Log.

Log of Rock Island Lines, deep well No. 2, at Glenrio, Deaf Smith County. Estimated elevation of curb, 3812 feet above sea level.

	Depth in feet below surface.	
	From	To
Red sand.....	1	8
Red sand and clay.....	8	32
Red shale.....	32	52
Hard red and blue shale, alternating layers.....	52	56
Red shale.....	56	120
Blue shale, mixed with sand.....	120	142
Red shale, mixed with sand.....	142	165
Gray sandstone.....	165	230
Water-bearing gray sandstone.....	230	255
Blue shale.....	255	262
Gray sandstone.....	262	280
Porous water-bearing gray sandstone.....	280	308
Blue shale.....	308	315
Porous water-bearing gray sandstone.....	315	324
Blue shale.....	325	334
Water-bearing gravel bed; "Tertiary gravels".....	334	366
Blue shale.....	366	376
Red clay and sand-streaked red clay.....	376	466

Blue shale	466	476
Concretionary red clay with white calcareous concretions	476	515
Blue shale and limestone.....	515	541
Brown sandstone	541	561
Sand-streaked red clay with layer of brown shale at top and thin streak of soft brown sandstone at 585 feet	561	625
Brown sandstone	625	652
Red clay	652	657
Brown sandstone	657	660
"Carboniferous" limestone	660	667
Sand-streaked brown clay.....	667	675
"Carboniferous" limestone	675	700
Brown sandstone	700	702
Red shale	702	720
Hard white rock; "feldspar".....	720	722
Red shale	722	742
Hard white rock; "feldspar".....	742	746
Red shale	746	795
Hard white rock; "feldspar".....	795	796
Red shale	796	800

Note.

Fresh water	230 to 255	in gray sandstone
Fresh water	280 to 308 ½	in gray sandstone
Fresh water	315 to 324	in gray sandstone
Fresh water	334 to 366	in "Tertiary gravels"
Small amount of salt water.....	585	feet
Water, less salty.....	700 to 702	feet

Samples.

Description of samples of cuttings from the Glenrio Well No. 2, made by the C. R. I. & P. Ry. Co. at Glenrio, Deaf Smith County. Submitted by Mr. Carl Scholz, Chicago, Ill.

	Depth in feet below surface.	
	From	To
Red surface sand.....	1	8
Yellowish red marl and some gray to yellowish red limestone, like "tepetate," and fine sand, mostly from ½ to 1-16 mm. in diameter.....	8	32
Bright red marly clay, containing some quartz sand, in which mica was noted.....	32	52
Purplish, grayish red, marly clay, containing some sand	52	56
Light red marly clay, containing a few fragments of light blue clay, some fragments of calcareous concretions, and some sand.....	56	120
A gray sandstone. Some of the larger grains are well rounded. Mica conspicuous. Much clear quartz. Some dark quartz. Some fragments are from a red sandstone in which the sand is held together by a calcareous cement	120	142
Brown sandy marly clay containing included blotches of greenish gray marl of similar composition. Fragments of calcareous concretions. Mica present....	142	165

Gray sand, mostly with grains from $\frac{1}{8}$ to $\frac{1}{2}$ mm. in diameter. Mica present. Some crystalline calcite noted. Sand mostly angular. Rock has a calcareous matrix	165	230
White sandstone, soft, micaceous, slightly cemented with calcareous material. Grains mostly angular, measuring mainly from $\frac{1}{8}$ to $\frac{1}{2}$ mm. in diameter..	230	255
A mixture of gray sand, silt, and clayey marl, containing some pebbles. Mica conspicuous. Some fragments of gray sandstone have a calcareous cement. A small part of red marl present.....	255	262
Gray sandstone with a calcareous matrix. Mica and pyrite present. Some of the quartz is pink in color. Size of sand mostly from $\frac{1}{8}$ to 1 mm. in diameter. A few small pebbles noted.....	262	280
Micaceous gray sand and gravel. The mechanical composition of the sand is about as below: Diam. of grains in mm. Percentages. 1- $\frac{1}{2}$ 20 $\frac{1}{2}$ - $\frac{1}{4}$ 60 $\frac{1}{4}$ - $\frac{1}{8}$ 15 $\frac{1}{8}$ -1-16 5 Sand grains are not well rounded, are slightly rough, as from etching. Quartz is mostly transparent and white, also green, pink and yellow grains. Mica conspicuous. Gravel is rounded and consists mostly of vein quartz and chert.....	280	308
Greenish gray and red micaceous silt containing some sand, small pebbles, and fragments of a calcareous sandstone	308	315
White and gray sandstone, cemented with calcareous material, micaceous. and containing fine gravel. Most sand from $\frac{1}{8}$ to 2 mm. in diameter. Not well rounded	315	324
Gray marly silt, slightly micaceous, and containing some sand	324	334
Sandy gravel. Coarsest pebble noted measured 1 inch. Material represented: white, black, yellow, chert; clear, white, and red vein quartz. Mica noted in sand	334	366
Greenish marly clay mixed with sand and pebbles, and containing fragments of a sandy limestone. Some quartz grains are very clear, some yellow, all are angular. Pebbles of white, blue, yellow and red chert. Mica and pyrite present.....	366	376
Brownish red and highly ferruginous sticky marly clay of fine texture, containing some sand and some fragments of red calcareous concretions and of concretions of limonite.....	376	466
Red marly clay of fine texture. Mica sparse. Fragments of red and white concretionary calcareous material noted. Small lumps of greenish gray clay present	476	515
A gray sandstone cemented with lime. Grains mostly from 1-16 to $\frac{1}{8}$ mm. in diameter. Mica present..	515	541

A mixture of brown and gray marly and clayey silt and sand. There are fragments of a light gray calcareous sandstone. Mica noted.....	541	561
Reddish sand, mostly from $\frac{1}{8}$ to $\frac{1}{2}$ mm. in diameter. Sparsely micaceous. A small part of sample is red clay	561	625
Reddish sand, mostly from $\frac{1}{8}$ to 1 mm. in diameter. Some of the larger grains are well rounded. Very little mica present. Slight quantities of clay and calcareous material present.....	625	652
Red marly clay. Mica not noted.....	652	657
A stony calcareous mud rock, dark brown and greenish gray, with some sand. Some poorly developed small quartz crystals noted. No mica seen.....	657	660
Cream-colored dolomite of very fine texture. In thin section it is seen to have minute angular porosities. Some of these have quadrangular shapes, indicating that they may be due to anhydrite crystals....	660	667
Dolomite, cream-colored, fine-grained, finely porous.....	675	700
Anhydrite	720	722
Anhydrite	742	746
Anhydrite	795	796
Bright red silty clay, hardly at all calcareous and containing no mica and very little sand. Some fragments of pure anhydrite present. The rock has greenish circular blotches several mm. in diameter.	796	800
Red sand, not micaceous. No label.....		....
Granular white anhydrite. No label.....		....
Red sand, slightly clayey. No mica noted. No label.....		....

Note.

The upper few hundred feet are in the Triassic red beds and sands. Below this are the Permian redbeds. The dolomite from 660 to 700 feet is probably the Alibates lenticle. "Feldspar," used in the driller's record, is a misnomer for anhydrite.

The Adrian Oil & Gas Company Boring.

The Adrian Oil & Gas Company, of Adrian, a station on the Pecos Valley & North Texas Railway, began a deep boring at Adrian in 1909. This boring was abandoned in 1911 at the depth of 2825 feet. Mr. C. A. Hale, now residing in Vega, was the contractor of the boring. A standard rig was used. It was cased down to 337 feet with a 16-inch casing, with a 12 $\frac{1}{2}$ -inch casing down to 490 feet, with an 8 $\frac{1}{4}$ -inch casing to 1530 feet, and with a 6 $\frac{5}{8}$ -inch casing to 2320 feet. The boring is located on the northwest edge of a flat depression in the land known as Rock Lake, near the center of Section 42, Block K11, in Oldham county, about two miles southwest of Adrian. Elevation of curb, estimated, 4050 feet above sea level.

Mr. C. A. Hale gives (1915) a memory record of the strata penetrated in this well. This is as below:

	Depth in feet below surface.	
	From	To
"Red banks".....	0	595
Dark shale.....	595	600
Soft honeycombed rock, looking somewhat like sand stone, and containing soft water, forming "soap suds"	600	640
Orange-colored mud.....	640	690
Gypsum and salt	690	750
Gypsum and salt, changing from one to the other every three to ten feet, or so.....	750	1185
Salt without break.....	1185	1370
Salt and gypsum	1370	1517
Sand like brown gas sand, no gas.....	1517	1547
Salt with gypsum.....	1547	2200
Dark rock (probably anhydrite).....	2200	2240
Salt	2240	2440
Shale, red, dark and gray, and red mud.....	2440	2875

Note.

The sand containing soft water at 600 feet is evidently Triassic, and the gypsum and salt at 690 is no doubt the uppermost of the Permian redbeds, which seem to continue to the bottom of this boring.

The Adrian Townsite Company Well.

After water had been found in the Adrian well No. 1 at 600 feet, a well was drilled on high ground about one-half mile southeast of Adrian. Water was obtained at depths of from 678 to 750 feet in a "honeycombed" gray sand. There was a layer of limestone eight feet thick, between the depths 614 and 622 feet. The remainder of the ground penetrated is described by the contractor, Mr. C. A. Hale, as red mud. A sample of mud from the dump of this well consisted of yellow, red and gray sandy silt and clay, in which scales of mica were noted. This boring evidently did not penetrate all the Triassic. The elevation of the curb of this well is estimated to be 4140 feet above sea level. Some cuttings of salt, anhydrite and clay were examined from this boring.

The Boden Boring.

Driller's Log.

Log of boring at Boden (also known as Field), Potter County. Drilled by Layne & Bowler Company, contractors, for the Amarillo Petroleum & Gas Company. The boring is located in the northeast

quarter of Section 4, Block 21W, East Line & Red River Railroad. Drilling begun June 10, 1914, was finished Sept. 23, 1914. Elevation: near 3250 feet above sea-level. Pipe was set as follows: 24-inch at 20 feet; 12-inch at 690 feet; 8-inch at 1458 feet; 6-inch at 1700 feet. "Pulled all pipe, except separated the 12-inch pipe at 70 feet from surface; balance of 12-inch pipe was left in well."

	Depth in feet below surface.	
	From	To
Soil	0	12
White clay.....	12	22
White sand mixed with charcoal.....	22	32
Blue clay.....	32	46
White sand mixed with charcoal, light flow of fresh water	46	50
Red clay.....	50	95
Gray rock.....	95	105
Red clay.....	105	115
Yellow rock.....	115	125
Red clay	125	165
Red sand with white shelly rock.....	165	190
Red clay	190	325
Red water sand (salt water), heavy flow, rose about 100 feet.....	325	340
Red clay	340	350
Red water sand (salt water).....	350	390
White rock	390	400
Red sand	400	465
Red sand	465	565
Red clay	565	615
Blue clay.....	615	633
Red shelly rock and salt.....	633	640
Salt	640	645
Red sand.....	645	650
Salt	650	665
Hard white rock.....	665	695
Blue clay.....	695	698
Dark red clay.....	698	701
Salt	701	710
Hard white rock.....	710	720
Salt	720	730
Brown sand.....	730	745
Hard gray rock.....	745	765
Hard white rock.....	765	770
Hard gray rock.....	770	775
Salt	775	785
Hard white rock.....	785	795
Yellow rock.....	795	800
Salt	800	810
Hard gray rock.....	810	850
Hard brown clay.....	850	855
Hard white rock.....	855	875
Salt	875	925
Blue clay.....	925	930
Salt	930	950
Hard gray rock.....	950	955
Blue rock.....	955	975

Hard white rock.....	975	1005
Salt	1005	1230
Blue rock.....	1230	1290
Salt	1290	1460
Blue rock.....	1460	1475
Blue shale.....	1475	1485
Red sandy clay.....	1485	1680
Red sand rock.....	1680	1690
Hard brown rock.....	1690	1720
Red sandy clay, with occasionally thin strata of salt..	1720	2010
Bubbles of gas noted.....	1900	2000

(Signed) T. H. LITTLE,
Superintendent, Layne & Bowler Company.

Samples.

Description of Cuttings from the Deep Boring at Boden, Potter County.

	Depth in feet below surface.	
	From	To
Brownish yellow sandy adobe.....	0	12
Gray siliceous clay of fine texture. Does not effervesce in acid.....	12	22
Gray fine sand and some brownish red sandy shale. With this is a considerable quantity of lignitic wood, like that found in the Triassic beds.....	22	32
Gray clay, giving no reaction to acid. It contains fine siliceous sand.....	32	46
Gray sand, grains mostly from 1-16 to $\frac{1}{2}$ mm. in diameter, of clear quartz, the larger sizes well rounded. Some red cherty fragments. Much lignite, showing woody structure.....	46	50
Red fine silt, slightly calcareous, containing red sand with grains mostly less than $\frac{1}{4}$ mm. in diameter..	50	95
Gray dolomite of very fine texture, with a few fragments of white and pink gypsum. One fragment of sandy and gypsiferous dolomite had many small pale green grains, seen in thin section.....	95	105
White gypsum, coarsely crystalline, and some red sandy clay	105	115
Gypsum, white and pink in color.....	115	125
Red clay, somewhat open in texture.....	125	165
Brownish red silty clay and gypsum. The red silt has light greenish specks or blotches. Clusters of cubic pyrite noted	165	190
Sandy dark red silt. Minute flakes of mica noted...	190	325
Red sand, with grains mostly from 1-16 to $\frac{1}{4}$ mm. in diameter	325	340
Red sandy and clayey silt, with some gypsum.....	340	350
Red sand of fine texture.....	350	390
White gypsum and some gray dolomite. Pyrite present and some salt. Potash, strong trace.....	390	400
Red sand, moderately fine in texture. Coarser grains rounded	400	465
Red sand, containing some silt.....	465	565
Light red silt showing some greenish gray blotches..	565	615

Mostly gray dolomite of fine texture. The crystals are clear cut in outline and quite uniform in size. The sample contains some red silt, some white anhydrite and a few flakes of selenite. Potash, trace.....	615	633
A mixture of gray dolomite of fine texture, white anhydrite, red argillaceous sandy rock and gypsum. Potash, trace	633	640
Salt in original crystalline fragments, and red sand and silt. Some gypsum and anhydrite. Potash, trace	640	645
Red sand with some fragments of green shale of very fine texture	645	650
Rock salt, red sand and some lumps of dark red shale. Potash, trace.....	650	665
Pure white anhydrite.....	665	695
Gray, marly shale or clay. Heated in a closed tube, it gives very strong fumes of sulphur and a deposit of sulphur on the inside of the tube. The material contains no pyrite. With low heat in an open casserole, pungent sulphur fumes are given off. It is believed the sample contains some free sulphur very finely divided.....	695	698
Dark brownish red, sandy and silty clay	698	701
Much salt and some red sandy silt. There are some chips of a silty gray shale, which is slightly micaceous. Gypsum noted. Potash, trace.....	701	710
White and gray anhydrite of compact texture. Some red silty material.....	710	720
Mostly pieces of clear salt. Potash, trace.....	720	730
Salt, with some red silt and some blue silt. The sample contains several fragments of a red rock composed of a mixture of salt and silt. Potash, trace..	730	745
White anhydrite of moderately fine texture.....	745	765
White anhydrite.....	765	770
Grayish white anhydrite with some brownish gray silt	770	775
White anhydrite, with a few fragments of red silt. Potash, trace	775	785
White anhydrite.....	785	790
Yellowish white anhydrite.....	790	800
White and yellowish anhydrite of moderately coarse texture. Potash, trace.....	800	810
Gray anhydrite, mostly of compact texture.....	810	850
Brownish red silt and white and variegated anhydrite, with scattered fragments of dolomite.....	850	855
Bright white anhydrite.....	855	875
Clear salt, with a few fragments of salmon-colored salt. The salmon-colored salt was picked out and analyzed and found to contain approximately 9.23 per cent. potash (K_2O), equivalent to 14.81 per cent. potassium chloride. These fragments may be a mixture of potash-bearing minerals, with some common salt. The colorless salt contains 0.66 per cent. potash (K_2O). Another sample of drillings from this depth, received later, consisted of chocolate-colored clay, in which were seen surfaces covered with quartz crystals, in an incrustated plate; anhydrite containing small bodies of salt, rock salt with clouds of red silt, and a matrix of gray anhydrite,		

showing moulds of cubic crystals of salt a half-inch in diameter. In ne of these moulds a salt-crystal remained undissolved	875	925
Mostly gray anhydrite, with some fragments of gray and red silt. Potash, trace,.....	925	930
Salt in fairly clear fragments. Potash, trace.....	930	950
Gray anhydrite	950	955
Dark, soft shaly rock giving strong fumes of sulphur when heated. With this is some anhydrite. No pyrite noted. Potash, trace.....	955	975
White, compact anhydrite, with some fragments of red and gray silt.....	975	1005
Pure salt. Trace of potash.....	1005	1230
Mostly gray, slightly impure anhydrite. In thin section one fragment shows the dark impurities distributed in a matrix, which incloses kernels of clear anhydrite of long straight crystals forming a network. One fragment showed thin laminae.....	1230	1290
Halite, anhydrite, red clay and silt and greenish-gray shale. The salt adheres to anhydrite in one piece, and to red silt in another lump. One piece of anhydrite has empty moulds of cubic form, evidently left by dissolved halite. Some of the red silt has blue blotches. When washed it is seen to contain small crystals of quartz. The anhydrite is fine in texture and gray in color. The greenish shale yields strong fumes of sulphur. Potash, trace.....	1290	1460
Gray anhydrite of fine compact texture. The gray color is apparently due to slight argillaceous impurity, which is present in streaks and blotches in some fragments	1460	1475
Gray, earthy, porous anhydrite of fine and uniform texture. It contains a small ingredient of silt and sand, and in this a few crystals of quartz were noted	1475	1485
Red sandy silt mingled with some anhydrite and containing a few clear pieces of halite. Octahedral pyrite noted. The sand contains small clear crystals of quartz. Most of the anhydrite is white and granular. Some is pinkish or gray and compact, some has a flaky character, and the flakes are composed of acicular crystals promiscuously oriented. Potash, trace	1485	1680
Red sand and silt with grains mostly from 1-16 to 1/2 mm. in diameter. In the coarsest sand, crystal of quartz were noted.....	1680	1690
Pure salt, mingled with some red silt. Trace of potash	1690	1720
Red silt, sand, and salt. The salt is in clear bodies in the sand. The red silty sand contains mica and also many small crystals of quartz. Potash, 0.14 per cent.....	1720	2010
One sample contains a lump of gray, very fine-grained anhydrite with an irregular 0.2-inch thick plate of red silt. One side of this lump shows cubic cavities, apparently places once occupied by salt crystals, 0.1 to 0.2 inch in diameter. The rest of this sample is lumps of red silt with irregular plates from 0.1 to 0.3 inch in thickness, of pure halite.		

Quartz crystals with two opposite pyramids and other more irregular quartz crystals occur among the larger sand grains. **Marked:** "All salt found in this formation".....Depth not stated

Note.

This boring passes through some Cenozoic land drift, then Triassic material down to fifty feet or more below the surface. From ninety-five feet down to the bottom of the boring the formations penetrated belong to the Permian redbeds.

The Miller Ranch Boring.

Driller's Log.

Log of Miller Boring No. 1, Randall County. Dug by Will A. Miller & Sons, 18 miles S. W. from Amarillo, in bed of Palo Duro Canyon. Work stopped March 1, 1914. Location: 7 miles from Canyon City. Sec. 24, Block A, Tyler Tap R. R. Co., Randall County. Finished Feb., 1914. Located on the bank of Palo Duro creek. Elevation: near 3680 feet above sea-level.

	Depth in feet below surface.	
	From	To
To cellar.....	0	7
Red clay.....	7	40
Water and sand.....	40	55
Red shale.....	55	85
Blue shale.....	85	125
Red and blue shale.....	125	220
Water sand.....	320	360
Red shale.....	360	370
Water sand.....	370	435
Red shale.....	435	445
Yellow mud.....	445	460
Red shale.....	460	465
Yellow shale.....	465	485
Red shale.....	485	510
Gray shale.....	510	530
Red shale.....	530	550
Sand.....	550	565
Red shale.....	565	585
Sand.....	585	595
Red sand and shale.....	595	630
Salt water and sand.....	630	640
Red shale and sand.....	640	655
Light red mud.....	655	745
Sand.....	745	750
Limestone, hard.....	750	765
Light red shale.....	765	940
Salt and red shale.....	940	1170
White lime rock.....	1170	1185
Red sand, water, "gyppy," corrosive.....	1185	1280
Lime rock.....	1280	1292
Red shale.....	1292	1325
Brown sand.....	1325	1385

Red shale.....	1385	1390
Rock salt.....	1390	1430
Dark gravel shale.....	1430	1435
Solid salt.....	1435	1500
Lime rock.....	1500	1508
Rock salt.....	1508	1530
White lime rock.....	1530	1544
Blue shale, sulphur.....	1544	1565
Red shale and salt.....	1565	1570
Salt, some shale.....	1570	1585
Solid salt.....	1585	1610
Lime rock, hard.....	1610	1635
Salt.....	1635	1680
White lime rock.....	1680	1695
Blue lime rock.....	1695	1700
Blue mud, salt.....	1700	1710
Blue and brown salt.....	1710	1720
Blue lime and some water.....	1720	1740
Blue shale.....	1740	1745
Hard lime.....	1745	1825
Red mud.....	1825	1830
Salt.....	1830	1950
Lime rock, blue.....	1950	2015
Blue shale.....	2015	2018
Lime.....	2018	2025
Salt.....	2025	2205
Brown shale.....	2205	2210
Lime and blue shale.....	2210	2212
Salt.....	2212	2315
Lime.....	2315	2440
Salt.....	2440	2480
Lime.....	2480	2530
Red and blue shale, into a dark shale, very sticky....	2530	2575

Samples.

Description of samples of cuttings from W. A. Miller & Sons' well, 18 miles southwest of Amarillo, Randall County, Texas.

	Depth in feet below surface.	
	From	To
Red sandy silt and clay with bluish-gray small round blotches, and containing a few very small flakes of mica. Some porous white gypsum, partly as small perfect crystals of selenite. Some fibrous white gypsum. Above and at.....		1325
Fragments of light gray, medium gray, and almost grayish black anhydrite. Heated in closed tube it retained its color and gave off some moisture. In open flame the dark color disappears. The dark color is perhaps due to carbonaceous matter. In thin section it is seen to consist of a tangle of flat-like crystals. This resembles some anhydrite noted at from 2042 to 2047 feet below the surface in the boring at Spur. The sample has some salt and this contains 6.14 per cent. of potash (K_2O).....	1500	1700
A sample of drillings consists of rock salt, dolomite and anhydrite. The bulk of the salt is in colorless		

broken crystals. This salt contains 2.79 per cent. of potash (K_2O). Two analyses were made of pink fragments occurring in this salt. One of these gave 1.72 per cent. and the other 3.23 per cent. of potash (K_2O) of the soluble portion. The anhydrite is white and granular. Some dolomite is quite pure, yellowish gray, some is mingled with anhydrite. In thin section two rock fragments were seen to consist of minute ill-defined rounded bodies of anhydrite imbedded in a sparse matrix of dark clayey and magnesian material. Some fragments were soft impure limonite.....	1700	2100
One large rock fragment, coming from below 1700 feet, consists of bright red sandy silt, having small spherical light gray spots. Another large fragment consists of compact anhydrite containing imbedded irregular crystals of salt from 1-16 to $\frac{1}{4}$ inch in diameter. Red clay adhered to this fragment. The salt in this anhydrite contains 10.50 per cent of potash (K_2O), equivalent to 15.80 per cent of potassium chloride		1700

Note.

Most of the reported limestone is probably anhydrite. There was a heavy stream of fresh water at 40 feet, rising to within eight feet of the surface. Some gas was noted at 1325 feet.

Mr. C. L. Baker, of this Bureau, regards the uppermost 430 feet in this boring as Triassic. All below this depth is believed to be Permian redbeds.

The McLean Boring.

Log of the Panhandle Oil & Gas Company Boring No. 1, on the O'Dell farm, about one-half mile south of McLean, Gray County. Elevation, estimated: 2810 feet above sea level. Made in 1914. Rotary rig used.

	Depth in feet below surface.	
	From	To
White seepage sand.....	10	20
Loose gravel.....	20	28
Bed of gravel, loose and hard in streaks.....	28	40
Hard running sand and gravel.....	40	80
White sand and some gravel.....	80	100
Light sand and pack.....	100	140
Water, gravel and boulders.....	140	170
Streak of clay and sand.....	170	175
Hard breaking rocks and gravel.....	175	180
Red sand rock.....	180	185
Soft "crested" rock.....	185	190
Red clay and sand.....	190	200
Soft sticky red shale.....	210	220
Hard light brown sand rock.....	220	231
Hard brown shale.....	231	240
Rock and hard lime.....	240	250
Dropping boulders and light brown rock.....	250	260

Soft lime and gypsum.....	260	285
Soft red shale.....	285	295
Hard brown shale.....	295	300
Soft sticky lime.....	300	310
Hard brown shale.....	310	330
Light gray quicksand.....	330	353
Sand, light brown and glassy.....	353	370
Soft shale and sand.....	370	390
Soft gypsum and sand.....	390	395
Loose gypsum and black shale.....	395	400
Hard gypsum rock.....	400	410
Hard rock, gypsum.....	410	420
Soft sand and gypsum.....	420	434
Hard white gypsum rock.....	434	444
Hard yellow sand and gypsum.....	444	450
Soft blue shale.....	450	465
Hard gypsum, sand rock.....	465	470
Soft white gypsum.....	470	480
Hard-breaking rock and boulders.....	480	490
Soft white gypsum and lime.....	490	523
Pure white gypsum and lime.....	523	530
Hard rock, blue shale and gypsum.....	530	535
Hard dark shale.....	535	550
Soft white and yellow gypsum.....	550	552
White gypsum.....	552	555
Coarse gypsum, sand and gas, and shale.....	555	560
Hard, clear and yellow rock.....	560	565
Hard gypsum, sticky clay.....	565	570
Hard sand rock.....	570	575
Hard, blue, gummy gypsum, clay.....	575	578
White chalk, gummy, paste, magnesia.....	578	583
Hard blue sand rock.....	583	585
Crystallized sand.....	585	586
Hard blue shale.....	586	590
Hard sand rock.....	590	593
Soft red shale and sand.....	593	597
Hard red and white "coral" rock.....	597	600
Hard sandstone and lime.....	600	622
Soft white rocky gypsum, mixed with shale and salt; also black mud.....	622	630
Loose shale.....	630	635
Soft white "chalk".....	635	642
Soft white gypsum, streaked with red shale.....	642	645
Hard, dry, red shale.....	645	647
Hard-breaking gypsum rock.....	647	650
Hard blue shale.....	650	655
White gypsum rock.....	655	657
Sand rock.....	657	662
Blue sand rock.....	662	665
Sticky black mud.....	665	670
Sand rock.....	670	673
Red shale.....	673	682
Blue mud.....	682	703
Soft blue shale.....	703	712
Soft blue shale.....	712	722
Dark brown, dry shale.....	722	730
Blue shale.....	730	732
Dark sand.....	732	743

Blue shale	743	750
Soft red shale.....	760	766
Red shale and yellow sand.....	766	770
Soft gypsum and red shale.....	770	775
White yellow sand, shale.....	775	782
Red shale	782	800
Soft lime, red sand, isinglass.....	800	820
Gray lime, isinglass, soft red shale.....	820	830
Soft lime	830	840
Hard streak of salt, lime, sand and gray lime.....	840	865
Soft and hard gypsum and "isinglass".....	865	883
Soft white gypsum and "isinglass".....	883	900
Red shale and gypsum.....	900	940
(Gas sand.....902 to 903 ft.)		
Streaks of hard gray lime and gypsum.....	940	960
Streaks of hard gray lime and gypsum.....	960	965
Red shale	965	970
Shale and brown sand.....	970	1000
Soft white gypsum and lime.....	1000	1015
Brown shale and sand.....	1015	1036
Streaks of hard gray lime and gypsum.....	1036	1070
Gypsum and lime, and red sand, crystallized.....	1070	1075
Isinglass, hard	1075	1090
Streaks hard blue lime and soft gypsum.....	1090	1150
White gypsum, lime and streaks of red shale.....	1150	1161

Casing set.

Red shale	1161	1175
White gypsum and soft blue lime.....	1175	1190
Gray lime	1190	1200
Limestone	1200	1215
Soft lime	1215	1218
Soft red shale.....	1218	1222
Pure white sticky gypsum.....	1222	1225
Brown shale.....	1225	1228
Red shale.....	1228	1230
Isinglass	1230	1233
Red shale	1233	1235
Hard gypsum and salt.....	1235	1240
Soft blue shale.....	1240	1275
Brown shale.....	1275	1280
Hard white gypsum.....	1280	1283
Soft red shale.....	1283	1290
Salt and white lime rock.....	1290	1300
Red shale and lime, blue shale and salt.....	1300	1350
Streaks of hard and soft lime, red shale and salt....	1350	1355
Soft sticky lime.....	1355	1360
Hard blue limestone.....	1360	1362
Red sand rock.....	1362	1370
Isinglass	1370	1380
Soft red shale and lime.....	1380	1390
Isinglass and lime.....	1390	1395
Red sand rock	1395	1397
Yellow rock.....	1397	1405
Brown shale.....	1405	1410
Hard blue and gray lime.....	1410	1440
Loose gypsum.....	1440	1441
Breaking red sand rock.....	1441	1442

Hard yellow brown rock.....	1442	1445
Mica and hard brown shale.....	1445	1450
Blue shale.....	1450	1460
Hard gray lime.....	1460	1465
Soft gypsum and soft yellow shale.....	1465	1467
Hard blue lime.....	1467	1468
Red rock.....	1468	1480
Soft lime and gypsum.....	1480	1490
Gypsum and gray lime.....	1490	1500
Gypsum, gravel and lime.....	1500	1518
Gypsum and "isinglass".....	1518	1520
Hard red and white rock.....	1520	1523
Hard sticky yellow rock.....	1523	1530
Hard limestone.....	1530	1532
Hard brown rock.....	1532	1533
Hard red rock.....	1533	1535
Hard white crystal rock.....	1535	1536
Red sand.....	1536	1538
Hard gray lime.....	1538	1541
Blue mud.....	1541	1543
Red mud.....	1543	1545
Soft limestone.....	1545	1546
Black sticky shale.....	1546	1550
Lime and red shale.....	1550	1555
Brown shale and shelly lime.....	1555	1560
Red shale.....	1560	1562
Soft gypsum.....	1562	1570
Hard white gypsum.....	1570	1575
Limestone.....	1575	1577
Shelly lime.....	1577	1587
White rock.....	1587	1589
Red brown shale and salt.....	1589	1593
Blue mud.....	1593	1600
Soft blue shale.....	1600	1610
Streaks of shelly lime and mixed shale.....	1610	1617
Soft gypsum.....	1617	1619
Hard lime.....	1619	1626
Lime, gypsum and red shale.....	1626	1630
Red shale.....	1630	1635
Soft mixture, red shale and shelly lime.....	1635	1637
Hard white and gray lime.....	1637	1645
Blue shale, soft, hard by streaks.....	1645	1665
Peculiar hard rock.....	1665	1670

Note.

An examination of thirty samples submitted from this boring by Mr. G. A. Anderson, and marked as coming from various depths between 673 and 1670 feet below the surface, in this boring, shows that they have an uncommon resemblance to each other, for samples representing different depths and presumably different deposits. Blue shale is comparatively rare in the samples between the depths 1000-1240 feet. It is the principal rock in a single sample labeled "1590 feet." Anhydrite is the principal material at four depths: 865, 1020, 1180, and 1200 feet. Anhydrite in the form of small free crystals or crystals in clusters which are partly or wholly free, is common in most samples, though not looked for in each case. They measure mostly from one-fourth to one mm. in diameter. Gypsum occurs in the form of fragments of thin fibrous

plates, from 1 to 2 mm. thick. Small crystals of selenite were common in the sample labeled 1590 feet. Red and greenish gray clay and silt was the principal material in the sample from 1650 to 1670 feet. The presence of bluish gray anhydrite suggests this was the rock in which the boring stopped, at 1670 feet. It was reported as hard rock.

It is evident that all the samples have been washed, and that heavy mud was used in drilling. All samples contain much iron from the bit and casing. None of the samples contains enough salt to be detected by taste. The unusual uniformity suggests that there has been much mixing of the returns. Perhaps the only conclusion that can with certainty be inferred from the examination of these samples is that the red beds extend down to 1650 feet below the surface, at the least.

Note.

In a letter dated Jan. 11, 1915, Mr. G. A. Anderson, of McLean, Texas, writes as follows: "We ran out of the salt before we reached the 1260-foot depth, and again before we reached the 1670-foot depth." Mr. Anderson was interested in watching the progress of the work at the time, and from his statement it is clear that beds of salt of considerable thickness were penetrated above the two depths he mentions. There was "oil show" at 550 feet, and at 1240-1260 feet.

The uppermost 180 feet is perhaps Tertiary and Pleistocene. The remainder of the boring is no doubt in the Permian redbeds.

Some Borings in and Near Childress.

1.

Log of the Fort Worth & Denver City Railway Company 2075-foot boring at Childress, Childress County, furnished by the Chief Engineer's office, Fort Worth, Texas. Boring finished in 1911. Elevation of curb: near 1877 feet above sea-level.

	Depth in feet below surface.	
	From	To
Red dirt.....	0	125
Gyp rock.....	125	130
Blue clay.....	130	145
Gyp rock.....	145	160
Blue clay.....	160	165
Red rock.....	165	175
Gyp rock and dirt.....	175	270
Brown clay.....	270	275
Gyp rock with red streak.....	275	340
Red clay and gyp rock.....	340	430
Red clay.....	430	500
Red clay and light shale.....	500	570
Shell rock.....	570	572
Clay.....	572	650
Red mud.....	650	680
Red mud and gyp rock.....	680	725
Red clay and gyp rock.....	725	750
Clay.....	750	1045

Red mud.....	1045	1080
Red clay.....	1080	1255
Limestone.....	1255	1265
Hard rock.....	1265	1280
Red clay.....	1280	1300
Red mud.....	1300	1340
Shale.....	1340	1527
Limestone.....	1527	1615
Red clay.....	1615	1875
Red sandstone.....	1875	1900
Red sandstone and light clay.....	1900	1935
Sandstone.....	1935	2005
Hard blue formation.....	2005	2060
Light red shale.....	2060	2075

2.

Log of the U. S. Weddington Boring, located about six miles northwest of Childress, Childress County, in the southwest corner of Survey 644, Block H, Western & North Western Railroad. It is situated on a slope at the head of a draw draining east. A rotary rig was used. Boring completed in 1914. Elevation estimated at 1860 feet above sea-level.

	Depth in feet below surface.	
	From	To
Record not given, mostly gypsum and red clay.....	0	423
Sand rock.....	423	428
Salt and sand rock.....	428	450
Sand rock.....	450	460
Gyp rock.....	460	465
Sand rock.....	465	469
Salt and sand rock.....	469	484
Salt and gyp rock.....	484	490
Gyp rock.....	490	494
Salt and gypsum.....	494	496
Salt and sand rock.....	496	501
Sand rock.....	501	503
Salt and sand rock.....	503	511
Sand rock.....	511	513
Gumbo.....	513	516
Hard rock.....	516	524
Salt and sand.....	524	530
Red and blue shale.....	530	564
Gyp rock.....	564	568
Gumbo.....	568	571
Shale.....	571	573
Hard rock.....	573	601
Hard sand rock.....	601	630
Soft sand rock.....	630	670
Rock.....	670	673
Gumbo.....	673	685
Rock.....	685	688
Gumbo.....	688	700
Red and blue shale with a little shell.....	700	764
Blue shale.....	764	776
Hard rock.....	776	782

Sand rock.....	782	790
Gumbo	790	799
Lime rock.....	799	811
Blue shale.....	811	814
Lime rock and red clay.....	814	848
Blue shale, some boulders.....	848	883
Lime rock.....	883	888
Soap stone.....	888	892
Hard rock.....	892	899
Lime, flint and honeycomb rock.....	899	909
Sand rock.....	909	919
Blue and red shale and boulders, light showing of oil.	919	958
Hard rock.....	958	961
Blue and red shale.....	961	968
Hard rock.....	968	983
Blue and red shale and shell.....	983	1030
Sand rock.....	1030	1045
Hard rock.....	1045	1072
Sand and shale.....	1072	1083
Hard rock.....	1083	1096
Shale and shell.....	1096	1114
Hard sand rock.....	1114	1135
Shale and boulders.....	1135	1140
Hard rock.....	1140	1143
Salt and sand rock.....	1143	1153
Hard sand rock.....	1153	1173
Soft sand rock.....	1173	1189
Hard sand rock.....	1189	1213
Soft sand rock.....	1213	1219
Brown shale, showing of oil.....	1219	1236
Hard sand rock.....	1236	1246
Soft sand rock.....	1246	1248
Hard sand rock.....	1248	1282
Soft sand rock, oil showing.....	1282	1300
Blue shale.....	1300	1319
Blue and brown shale.....	1319	1334
Sand rock.....	1334	1342
Black gumbo.....	1342	1352
Hard sand rock.....	1352	1394
Soft sand rock.....	1394	1398
Oil sand, oil showing.....	1398	1399
Shale and shell.....	1399	1412
Sand rock.....	1412	1424
Shale and shell.....	1424	1440
Lime rock.....	1440	1459
Hard rock.....	1459	1462
White lime.....	1462	1464
Hard shell rock and lime.....	1464	1478
Sand rock.....	1478	1481
Blue and red shale.....	1481	1492
Blue shale, shell rock and gumbo.....	1492	1507
Shale, boulders and red clay.....	1507	1527
Blue shale.....	1527	1535
Red mud.....	1535	1547
Red shale.....	1547	1557
Blue and red shale.....	1557	1587
Red shale.....	1587	1598
Soft lime rock.....	1598	1602

White flint rock.....	1602	1628
Soft sand rock.....	1628	1630
Black gumbo.....	1630	1635
Lime rock and yellow mud.....	1635	1656
Blue shale and shell.....	1656	1675
Shell rock.....	1675	1686
Lime rock.....	1686	1700
Soft lime.....	1700	1719
Soft sand rock.....	1719	1724
Hard rock.....	1724	1735
Sand rock.....	1735	1745
Black gumbo.....	1745	1748
Sandy lime rock.....	1748	1749
Shale and gumbo.....	1749	1766
Gray shale.....	1766	1774
Blue shale.....	1774	1777
Sand rock.....	1777	1784
Blue shale.....	1784	1785
Gray shale.....	1785	1788
Lime rock.....	1788	1796
Shell rock.....	1796	1800
Sandy limestone rock.....	1800	1811
Gray shale and shell.....	1811	1819
Sand rock, crystallized.....	1819	1822
White lime, blue and red shale, with little gumbo....	1822	1896
Sand.....	1896	1900
Sand rock, red, crystallized.....	1900	1916
Hard limestone rock.....	1916	1933
Soft white lime.....	1933	1940
Red clay and limestone rock.....	1940	1955
Hard limestone rock.....	1955	1961
White muck.....	1961	1962
Dry red clay.....	1962	1970
Black shale, white muck, gumbo, shale and yellow sand, oil showing.....	1970	1990
Sandy limestone.....	1990	1992
Red muck, white lime.....	1992	2003
Sandy limestone.....	2003	2004

3.

Section of a shallow well made by the Fort Worth & Denver City Railway Company, at Childress, Childress county. From U. S. G. S. Water Supply and Irrigation Paper, 148, Pl. XXII, C. Elevation, near 1877 feet above sea-level.

	Depth in feet below surface.	
	From	To
Red clay.....	0	50
Gypsum.....	50	70
Red clay.....	70	95
Gypsum.....	95	110
Red clay.....	110	130
Gypsum.....	130	140
Red clay.....	140	150
Gypsum.....	150	155
Red clay.....	155	298

Red beds.....	298	525
Blue clay.....	525	535
Red clay.....	535	655
Red clay.....	655	747
Flint.....	747	750
Red clay.....	750	754
Packsand.....	754	782
Red clay.....	782	786
Red rock.....	786	807
Packsand.....	807	844
Gypsum.....	844	848
Salt.....	848	1098
"Gyp" clay.....	1098	1118
Salt.....	1118	1138
Gypsum.....	1138	1148
Red and blue clay.....	1148	1163
Sticky clay.....	1168	1178
Salt.....	1178	1203
Gypsum.....	1203	1218
Salt.....	1218	1238
Red, blue clay.....	1238	1253
Joint clay.....	1253	1263

4.

Description of samples from the Cooper Well, about one and one-half miles east of Childress, Childress county. Made in 1914. Estimated elevation: 1810 feet above sea-level.

	Depth in feet below surface:
Gray shale and a little anhydrite. The sample contains a few fragments of oolitic dolomite, which is porous, the interiors of the ooliths being dissolved. In thin section, the ooliths are seen to vary much in size.....	1260
Some gray dolomite of fine texture, some gray silt, and some anhydrite. Honey-combed rock with drusy anhydrite noted. Some oolitic dolomite present. In thin section the ooliths are seen to be mostly filled with dolomite. A few are filled with anhydrite. A few are empty. The oolite is like some rock at 2264 and 2709 feet in the Spur well.....	1430
Gray sandy shale, red silt, and white and pink anhydrite.....	1445
Gray silty material and anhydrite, and fragments of oolite from which the interiors of the ooliths have been dissolved out, making the rock porous. These fragments resemble rock seen on the surface at Childress. In thin section of oolite, it is found to have some ooliths filled with anhydrite, as in samples at 2264, 2624, 2709 and at 3245 feet in the Spur well.....	1460
Gray sandy shale, red silt, and anhydrite.....	1470
Gray dolomite, some red and some gray sandy silt and anhydrite. Drusy anhydrite noted on some fragments.....	1475
Gray sandy silt, gray anhydrite, and gray dolomite, in about equal quantities. Some porous oolite noted.	

Some honey-combed rock fragments have surfaces covered by drusy anhydrite.....	1500
Gray sandy dolomite, with some anhydrite.....	1550
Pink and gray anhydrite and some gray silt.....	1560
Greenish gray silt and pink and white anhydrite.	
Much drusy anhydrite noted, incrusting the surface of some fragments.....	1600

Note.

Oolitic dolomite occurs in outcrops near this well, and it appears in the cuttings down to 1500 feet. In the Spur well, oolites of this kind were noted at intervals, from 1200 to 2673 feet below the surface. The section shown in this well probably corresponds roughly to the lower part of the redbeds in the Spur well, and extends some 1000 feet into the upper part of the Dolomite Beds in the Spur well.

The data obtained from the four borings from near Childress are interesting in that they illustrate the wide divergencies of interpretation by drillers when prospecting new and unknown ground made up of such poorly defined types of rock, as constitute the formations in this region. Some salt beds were evidently overlooked in the deep boring by the Ft. Worth & Denver City Railway Company, owing, perhaps, to the presence of silty matter in the salt. It is believed that salt beds are present from 848 to 1238 feet below the surface, that some of the limestone reported is anhydrite, and that the lower part of the deepest wells extends into the Dolomite Beds of the Spur well. Conjectures beyond this seem hardly warranted at the present time.

The Spur Boring.

For data on the Spur boring, a section of which is shown in Plate 2, the reader is referred to Bulletin of the University of Texas, No. 363, entitled "The Deep Boring at Spur.*"

Boring at Post City.*Engineer's Log.*

Log of Double U Company well No. 2, at Post City, Garza county. Estimated elevation: 2700 feet above sea-level. Log taken January 19, 1912.

	Depth in feet below surface.	
	From	To
Surface	9	21
White gyp.....	21	63
Red clay.....	63	78
Sand	78	83
Water sand.....	83	104
Clay	104	108
Clay and gravel.....	108	125

*This publication is now out of print.

Gravel and sand.....	125	133
Red clay.....	133	187
10-inch casing set at 138 feet.		
Red and white rock, probably sand rock.....	187	207
Red plastic clay.....	207	264
Sand rock.....	264	310
Blue shale.....	310	331
Red sand rock.....	331	380
Red clay.....	380	484
Red rock.....	484	505
Red gumbo clay.....	505	545
White sand rock.....	545	547
Green clay shale.....	547	568
Same, and sand rock.....	568	629
Green clay shale.....	629	691
Red clay shale.....	691	754
Red and green clay shale.....	784	794
Red clay shale.....	794	815
Same, and sand rock.....	815	836
Sand rock and compact shale.....	836	857
Same.....	857	899
Hard compact red clay shale.....	899	964
Red clay, hardened. Well rounded pebbles, $\frac{1}{4}$ inch in diameter. Water came in at this depth, rose to within 100 feet of surface.....	964	968
Soft red shale, nodules of harder compact clay. Micaceous sandstone and crystalline gypsum....	968	1000
Strata of crystalline gypsum, compact red clay shale.....	1000	1066
Dark red and green clay shale.....	1066	1140
Same, with streaks of calcite.....	1140	1145
Same.....	1145	1182
Dark red clay shale, greenish lime shale with narrow sandstone strata.....	1182	1217
Dark red clay shale with hard lime pebbles.....	1217	1234
Compact red and greenish clay shale.....	1234	1280
Same.....	1280	1284
Soft chalky gypsum.....	1284	1286
Hard compact gypsum rock.....	1286	1288
Compact red and greenish clay shale.....	1288	1296
Same, cored.....	1296	1298
Same.....	1298	1310
Fine grained red sandstone.....	1310	1314
Compact red clay, heavy with salt.....	1314	1318
Red sandstone, with streaks of satin spar, cored....	1318	1324
Red clay shale with red (thin) sandstone and gypsum strata.....	1324	1336
Red sandstone and gypsum strata.....	1336	1344
Thin salt bed on red stone (sand).....	1344	1346
Red clay shale, strata red stone (sand), 2-4 feet thick.....	1346	1368
Hard compact clay shale.....	1368	1374
Red clay shale with red sandstone and white lime and gypsum strata. Red clay shales heavy with salt above sand rock.....	1374	1394
Red clay shale with strata of red sandstone and salt-saturated clay.....	1394	1442
Red clay shale and red sandstone with small seams of white lime.....	1442	1468
Same as above.....	1468	1558

Red clay shale and red sand rock with occasional narrow strata of altered lime rock.....	1558	1604
Hard compact silicified lime rock.....	1604	1628
Red clay shale; red sandstone; less salt, small quantity gas	1628	1650
Hard red silicified lime rock; small quantity of gas noted	1650	1656
Red shale, heavy with salt.....	1656	1672
Salt rock	1672	1674

Samples.

Description of samples of cuttings from Double U Company well No. 2, Garza county. Samples furnished by the Double U Company.

	Depth in feet below surface.	
	From	To
Pink and red marl, some quite argillaceous, some more calcareous; and gray imbedded sandstone...	878	880
Red marly clay and some greenish gray clay.....	880	888
Red marly silty clay.....	894	896
Like the preceding.....	896	898
Like the preceding.....	898	900
Dark red slightly marly clay, with some green clay..	900	902
Red marly clay, much pink calcite, apparently from concretions; greenish gray and red sandstone of fine texture	902	904
Red marly clay.....	904	906
Red and green clay, slightly marly, with some concretionary gray lime, in fragments.....	906	908
Pink and dull red marl containing some sand. Octahedral and cubic pyrite noted, octahedral crystals simple and nearly 1 mm. in diameter. Mica noted, some gypsum or anhydrite.....	908	910
Red marly clay and clayey sand. Pyrite, cubic, noted; also gypsum and fragments of pink calcareous concretions and mica.....	910	920
Red, slightly marly, clay.....	920	930
Red clay, slightly marly and sandy. Pyrite, gypsum, and quartz pebbles noted, also mica.....	930	936
Red silt, with occasional gray blotches.....	936	940
Like the preceding.....	950	964
Red marl, marked "Taken from the bit," at.....		966
Red clay of fine texture, with some gray calcareous blotches	964	968
Red marl, marked "taken from bit".....	968	973
Red marl.....	973	980
Red marl with gray blotches. Mica noted.....	980	995
Red marly clay, with some concretions of gray lime..	995	1000
Red silty marl, mica noted.....	1000	1005
Red marly clay, with some gray and red concretionary material	1005	1010
Red clay and red marl.....	1015	1030
Red marly clay and silt. Mica noted.....	1030	1040
Like the preceding.....	1040	1055
Like the preceding.....	1062	1077
Red silty clay marl, with green blotches.....	1077	1087
Red clay marl with some green marl.....	1087	1108

Red marly clay.....	1108	1120
Red marly clay, pyrite noted.....	1120	1130
Red marly clay, with some fragments of powdery and other gypsum, and some greenish gray marl.....	1130	1140
Red marly shale or clay.....	1140	1145
Red shale, dark red marly clay and some concretion- ary lime	1145	1148
Red and dark red shale and marly clay. Small quartz pebbles and gypsum present.....	1148	1150
Dark red clay and shale, in part marly. Concretion- ary lime noted.....	1150	1155
Red silty clay with small greenish gray streaks. Mi- nute mica scales noted.....	1155	1160
Like the preceding.....	1160	1162
Like the preceding.....	1162	1164
Like the preceding.....	1164	1166
Red silty marl.....	1166	1168
Like the preceding.....	1168	1170
Like the preceding.....	1170	1172
Red shale and some greenish gray calcareous ma- terial	1172	1174
Red marly clay, with greenish gray blotches.....	1174	1176
Red marly clay with fragments of greenish gray con- cretionary limestone.....	1176	1178
Red marly clay.....	1178	1180
Red silty marl with some greenish fine sand and some red concretionary lime.....	1180	1182
Red marly clay, with fragments of greenish gray sandy rock.....	1182	1184
Dark red marly clay, and some fragments of greenish gray clay	1184	1186
Red marly clay.....	1188	1190
Like the preceding.....	1190	1192
Like the preceding.....	1192	1194
Like the preceding.....	1194	1197
Like the preceding.....	1197	1198
Like the preceding.....	1198	1217
Red marly clay, with rare greenish gray streaks.....	1218	1220
Red marly clay.....	1222	1224
Like the preceding, with some greenish gray frag- ments	1224	1226
Red marly clay, with some pink and some almost black calcareous concretionary fragments.....	1226	1228
Red marly clay with some lumps of dark purple clay and some fragments of sandy rock cemented with loose calcareous concretionary material.....	1230	1232
Red marly clay, and some light greenish gray calcare- ous rock	1232	1234
Like the preceding.....	1234	1238
Red marly clay.....	1239	1240
Like the preceding, and some fragments of greenish gray marl.....	1240	1242
Like the preceding, and some gray and purplish frag- ments of marly clay. Gypsum and pyrite noted...	1242	1244
Red marly clay and fragments of light gray and dark gray calcareous material. Mica noted.....	1244	1246
Red marly clay with fragments of calcareous ma- terial	1246	1258

Red marly clay.....	1258	1262
Red marly silty clay, with fragments of concretionary calcite and some gypsum. Mica and pyrite noted. Some quartz sand.....	1262	1264
Red marly shale.....	1264	1268
Red marly clay	1268	1270
Red marly clay and some light greenish gray and white limey fragments.....	1270	1272
Red marly clay and shale and some fragments of red calcareous concretionary material.....	1280	1282
Red marly clay and some bluish calcareous material..	1282	1284
Pure white anhydrite of microscopic crystalline texture	1284	1286
Anhydrite, taken from bit.....	1286	1288
Red silt, with some fragments of calcareous concretions	1288	1290
Red marly silt.....	1290	1296
Red micaceous silt and clay, with fragments of gypsum and lime and rounded grains of quartz.....	1306	1326
Red marly silt and clay with some fragments of bluish gray shale and some of anhydrite and limestone. Some coarse round quartz grains.....	1298	1384
Red marly clay and silt. Some fragments show layers of greenish gray color.....	1384	1386
Red marly clay and shale with some fragments of light gray lime and anhydrite, and gray rock.....	1386	1392
Red marly silt and clay.....	1396	1450
Red silty marl and clay with fragments of anhydrite, concretionary lime and rounded quartz grains....	1450	1488
Red clay and sandy silt with calcareous fragments and crystals of gypsum and large fragments of anhydrite crystals	1488	1490
Red sandy and marly clay containing some anhydrite and some small selenite crystals.....	1490	1492
Pale red silty clay. The sample has caked apparently from the presence of anhydrite and salt. Small selenite crystals present.....	1492	1494
Like the preceding.....	1494	1518
Pale red marly and silty clay with anhydrite and selenite	1518	1536
Red marly and silty clay with anhydrite and selenite.	1536	1538
Pale red marly and silty clay with crystals of selenite and fragments of anhydrite.....	1538	1570
Pale red marly and silty clay.....	1570	1572
Red silty and marly clay with fragments of anhydrite	1572	1576
Red sandy, silty clay with minerals as above.....	1576	1578
Red sandy, silty clay.....	1578	1616
Red silty and marly clay with selenite and anhydrite. A crystal of double pyramidal quartz noted.....	1616	1618
Red silty, marly clay.....	1618	1632
Red sandy and marly clay with crystals of gypsum and anhydrite	1632	1640
Red silty clay with minerals as above and a few green fragments	1640	1646
Red silty and marly clay.....	1646	1652
Red silty clay with crystals of selenite, fragments of anhydrite and clusters of quartz crystals.....	1652	1670

Red silty clay with crystals of quartz, fragments of anhydrite and radiating clusters of anhydrite....	1670	1672
Like the preceding, but with more anhydrite.....	1672	1674
Anhydrite, white, powdered and caked, second sample.	1672	1674
Red silty clay and anhydrite, with crystals of selenite, anhydrite and quartz.....	1674	1676
Red silty clay and some anhydrite.....	1676	1678
Like the preceding.....	1678	1694

Note.

Between the depths of 878 and 1694 feet no less than 108 samples of cuttings have been examined from this boring. These samples consist for the most part of mixtures of red marly silt, sand, anhydrite and gypsum, and verify the driller's log in several points. Pebbles of quartz and some sand are present at from 930 to 936 feet. There must be a conglomeratic sandstone near this depth. Quartz pebbles one-fourth inch in diameter are reported by the driller at from 964 to 968 feet. Calcareous material appears in the cuttings from 1150 to 1200 feet, where the driller reports several thin layers of limestone. A thin layer of gypsum shows in the driller's record at from 1284 to 1288 feet. The samples at this depth show that this was a layer of anhydrite, and that therefore the driller was right in differentiating it from limestone. The thin limestone layers reported by the driller from 1500 to 1558 feet seem from the cuttings to have been anhydrite. Both sources of information indicate the presence of some precipitated sediment, limestone, or anhydrite, or a mixture of both at about from 1600 to 1630 feet below the surface. The hard, red, silicified limerock reported from 1650 to 1656 feet is represented in the samples by limestone. The salt rock reported at from 1672 to 1674 feet must have contained considerable anhydrite, which appears in the cuttings.

Pyrite was noted in the cuttings at 908-910, 1120-1130, 1242-1244, and 1262-1264 feet below the surface. Crystals of quartz, which seem to characterize the salt, anhydrite, and gypsum-bearing red beds, were noted in the cuttings at 1616-1618, at 1670-1672, and at 1674-1676 feet. Free clusters of anhydrite are often associated with these quartz crystals. They were noted in these samples at the three depths mentioned last. From the cuttings it appears that the ground contained some salt between the depths 1492 to 1518 feet. Small crystals of selenite were seen in the cuttings quite frequently from various depths, and the hydration of the anhydrite seems to extend to a greater depth in this boring than in most other explorations on the Plains.

The "white gyp" reported by the driller at from 21 to 63 feet, I take to be some soft, white, marly material, perhaps belonging to the Pleistocene. The clay gravel and sand reported at from 108 to 133 feet is doubtless the basal gravels of the Triassic. The beds below this are all to be referred to the Permian redbeds. The red rock, which is reported from 484 to 505 feet as separate from a red clay above and a red gumbo clay below, is in a horizon near that of the Alibates limestone lentil in the Glenrio well.

The Justiceburg Boring.

The Panhandle & North Texas Railway boring at Justiceburg, Garza County. Elevation: 2312 feet above sea-level.

The depth of this boring is 600 feet, and all is in the Permian

redbeds. These consist mostly of gypsum in the upper 100 feet, and below this of red sandy silt. Salt was noted in several places below 400 feet, and the last 15 feet were in rock salt. Information from Mr. C. L. Baker, of this Bureau.

The Snyder Boring.

Driller's Log.

Log of Snyder Development Company boring, located at Snyder, Scurry county. Elevation, estimated, 2400 feet above sea-level. S. K. Reese, driller to depth of 800 feet; Norwood Bros., to 1660 feet. Six-inch casing set at 1002 feet. Below this, the well was open. A rotary rig was used. The boring was made in 1912 as a test for oil.

	Depth in feet	
	From	To
Hard white sand.....	0	105
Hard red sand.....	105	115
Soft white sand.....	115	145
Hard white sand.....	145	155
Coal, 4 inches thick.....	155	165
Coal, 12 inches thick.....	165	170
Hard sand rock.....	170	185
Red clay.....	185	200
Red shale.....	200	250
Red rock.....	250	365
White sand.....	365	385
Red shale.....	385	390
Red rock.....	390	400
Gypsum.....	400	405
Red rock.....	405	410
Red clay.....	410	425
Red sand.....	425	440
Red rock.....	440	450
"Bed of lode stone".....	450	485
Red sand rock.....	485	490
White rock.....	490	500
Oil sand.....	500	505
Same.....	505	510
Red sand rock.....	510	515
Red clay.....	515	520
Hard red rock.....	520	550
Red clay.....	550	640
Hard red rock.....	640	655
Salt water (and salt rock).....	655	695
Salt rock.....	695	705
Red rock.....	705	720
Salt rock.....	720	765
Red rock.....	765	770
Salt rock.....	770	775
Red shale.....	775	785
Salt rock.....	785	800
Clay, gravel and salt.....	800	840

Red rock, sand.....	840	860
Sand rock.....	860	870
Clay, gravel mixed with salt.....	870	1020
Red sand rock.....	1020	1040
Gravel.....	1040	1140
Sand rock.....	1140	1160
Pack sand, red.....	1160	1285
White rock.....	1285	1315
Pack sand, red.....	1315	1330
Red rock, sand.....	1330	1345
Red sand.....	1345	1380
White rock.....	1380	1570
Salt, and shale.....	1570	1600
Shelly rock, mixed with shale.....	1600	1625
Red sand mixed with salt and shale.....	1625	1660
White lime rock and salt.....	1660	1725
Hard red sand, gypsum and salt.....	1725	1805
Gray lime rock.....	1805	1905
Gray lime, rock salt and sand.....	1905	1955
White rock.....	1955	2000
Red sand rock.....	2000	2120
Gray lime rock.....	2120	2130
Salt rock.....	2130	2160
Red sand rock.....	2160	2195
Red sand and gray lime.....	2195	2220
Hard sand and salt water.....	2220	2290
Red sand.....	2290	2360
Gray lime.....	2360	2385
Gray lime mixed with sand.....	2385	2430
Red sand rock.....	2430	2500

Samples.

Description of samples from the Snyder Development Company boring, Snyder.

	Depth, in feet, Below surface.
From	To
Red clay shale and gray shale.....	Surface
Red sand of fine texture, with some fragments of fine textured limestone, some fragments of selenite and some small crystals of quartz. Sample salty.....	1675
A sample of anhydrite of light gray color and compact texture came up on the bit from depth of....	1700
Red sand, of fine grains, with some gray limestone, some granular anhydrite, and crystals of quartz. Sample salty.....	1725
Mainly gray and light gray limestone, effervescence slow. Some of the gray limestone shows indistinct imbedded darker particles $\frac{1}{8}$ - $\frac{1}{4}$ mm. in diameter, like fossil fragments or ill-shaped oolites. Some fragments of white and gray granular anhydrite noted. Some red sandstone of fine texture..	1750
Mostly gray limestone, having dark flexuous parallel streaks in some fragments; effervescing slowly. These may be of organic origin. Some red fine sandstone, and some fragments of dark shale. Several fragments of chert were noted, also some fragments of anhydrite.....	1790

Gray and white limestone. Some of the gray limestone is like that at 1750 feet. With this is some red sandstone, fine in texture, some quartz crystals, some selenite and some granular anhydrite.....	1810
Mostly a gray limestone, characterized by imbedded dark gray fragments from $\frac{1}{8}$ - $\frac{1}{4}$ mm. in diameter. No fossils noted. With the limestone is some chert, some anhydrite, and some red sandstone.....	1865
Gray dolomite. Some fragments show a finely laminated structure. Some fragments are of a darker rock. Some grains of selenite and some granular anhydrite were noted, also some minute crystals of pyrite, some chert with microscopic straight spicules, red sand, drusy quartz, and one double pyramidal crystal of quartz. No fossils found...	1885
Mostly gray dolomitic limestone, some red sand and some anhydrite. There were also some quartz crystals, and some bluish white chert. The limestone is in some fragments characterized by exceedingly thin and wavy foliations.....	1900
Like the preceding.....	1905
Gray dolomitic limestone, in which are imbedded minute dark crystals of anhydrite. Considerable chert was present.....	1910
Like the preceding.....	1915
Like the preceding.....	1920
Gray dolomitic limestone. Some quartz crystals were noted	1925
Gray dolomitic limestone, with an admixture of red sand	1930
Like the preceding, but with less sand.....	1935
Gray dolomitic limestone with a considerable admixture of red sand. Some chert noted.....	1940
Like the preceding	1955
Like the preceding, but with more sand.....	1985
Like the preceding	1990
Gray dolomitic limestone, with some red sand.....	2000
Yellow limestone, some dark gray limestone, some red shale, and some fragments of anhydrite. The yellow limestone has irregular dirty black blotches and is dolomitic. The dark gray or black limestone is not dolomitic. The anhydrite is granular, white or bluish gray, translucent, in thin fragments. Some anhydrite is bright pink in color. Test for potash negative	2293
Largely quartz sand of fine texture, the grains being moderately rounded and incrustated with oxide of iron. Some fragments consist of sand grains imbedded in anhydrite. Fragments of limestone are also present. There are some clusters of small quartz crystals. Some soluble salts are present and some anhydrite.....	2335
A yellow dolomitic limestone. Some fragments show black streaky specks, and some contain imbedded crystals of anhydrite. Some chert was noted, near.	2400
Fine-grained sand, imbedded in a matrix of anhydrite. The sand grains are moderately rounded. In the depressions on their surface there is usually a coating of bright red hematite.....	2465

Fine red sand fairly well rounded. Some fragments of the rock show the sand imbedded in anhydrite. The material contains clusters of crystals of quartz of minute size. There were also some crystals of anhydrite	2475
Mostly fine red sand, fairly well rounded, like the sand in the preceding sample. There were also fragments of a gray limestone, with streaky specks of black, and clusters of microscopic crystals of quartz	2485
Like the preceding.....	2500

Note.

The following is quoted from a letter from Mr. R. S. Jackson, Snyder Development Co., Snyder, Texas, May 24, 1912:

"I am sending you a sample of white rock taken from the well somewhere about 1700 feet. It is part of a piece that came out on the bit. When the drill went through it, the rock was ground up so fine it dissolved in the water and left no sediments. We passed through several strata of this rock. The water at times would be milk white. Another white rock passed through would ball up on the bit into a kind of gum. This latter rock was first found above the oil sand at a depth of 505 feet."

The uppermost 1700 or 1800 feet of this boring is in the Permian redbeds. Below this the formation is believed to be equivalent to the dolomites in the Double Mountain Formation, and to part of the Dolomite Beds in the Spur boring.

The Scoggin Boring.

Scoggin No. 1. Located about 800 yards east from the west boundary of Kent county, on the Yellow House Canyon. This boring was being made by the Yellow House Oil Company, of Dublin, in 1913. Elevation: near 2100 feet above sea-level.

The data on this well are not available from any authoritative source, but the fact seems well established that salt beds were encountered at 880 feet and continued at intervals from this depth down to 961 feet.

The Upland Boring.

Log of a part of a boring made at Upland, Upton county, in 1910. The boring is located in the west part of the town, and the curb has an elevation estimated to be near 3100 feet above sea-level.

	Depth, in feet, Below surface.	
	From	To
Soil	0	2
Limestone	2	90
Red sand.....	90	135
White sand, with water.....	135	160
Red clay.....	160	262
White sand, with water.....	262	300

Red clay.....	300	340
White sand, with water.....	340	356
Streaks of red clay and sand rock.....	356	405
Water sand.....	406	415
Sand and clay. The clay is red and light gray, changing every two to three feet.....	416	510
Water sand.....	511	530
Sand and clay, changing from red to white and blue..	530	700
Water sand.....	701	715
Sand and clay, red, gray and blue, changing every few feet	715	814
Sand rock	814	835
Limestone	835	860
Red sandy rock, shale or clay.....	860	1100
Water sand, with bitter and salt water.....	1100	1120
Red sandy rock, with streaks of clay. In this red clay are lumps of white material, which, when powdered by the drill, floats up on the water.....	1120	1300
Boring was being made deeper in 1913. Finished depth not known.		

Note.

The limestone from 2 to 90 feet is Comanchean, as also the sandstone immediately below this. The presumption is that at least the upper part of the vari-colored clays with water-bearing sand reported from 160 to 835 feet also belong to the Comanchean, but it is quite possible that the lower part of this division may be Triassic. From 860 to 1300 feet is without doubt Permian redbeds. Salt and bitter water is reported from sand between 1100 and 1120 feet below the surface. At the depth of 1300 feet the driller reported that there had been very small returns of cuttings for some time, and it appeared likely that he was then drilling in a salt bed or in a salt-bearing red silt. A small sample was like the returns from such salt-bearing silt seen in other explorations.

The Buena Vista Boring.

Rocks explored in a part of a boring made by the United States & Mexican Trust Co., at Buena Vista, Pecos county, on Survey 23, Block 2, Houston & Texas Central Railway lands. Estimated elevation: 2400 feet above sea-level.

	Depth, in feet, Below surface.	
	From	To
Adobe soil.....	0	25
Sand and gravel.....	25	220
Red shale and clay, containing hard black pebbles, all through, and having a thin stratum of sand at 450 feet		
Blue pyritiferous shale.....	220	531
Red sandstone.....	531	555
Red clay, containing layers of sandstone and white gypsum	555	588
Not known, except from two samples of cuttings of pure white gypsum, taken at 700 and 900 feet, and from statements by the driller that rock salt occurred at 962 feet and at 975 feet.....	588	620
	620	1000

Mainly red silty gypsum-bearing shale or clay, with thinner beds of gray shale. Some cream colored and white limestone at 1377 feet and below. This part of the record is known from 23 samples of cuttings, taken from 4 to 95 feet apart. Some of the red clay had gray blotches. Some minute crystals of quartz were noted. A cream colored limestone was somewhat copious in a sample from 1377 feet, and twenty feet below this a silty clay contained minute spherical yellow calcareous concretions. Most of the samples contained some calcareous material. Pyrite was noted in some of the gray or bluish gray shale.....1000 1414

Note.

The uppermost 220 feet is believed to be Pleistocene, probably a river drift. From 220 to 588 feet is most likely Triassic. From 588 down as far as the record extends, is no doubt Permian red-beds. It is probable that these contain more salt than would appear from the two isolated mentions of rock salt by the drillers, who stated that cuttings from some parts of the boring were difficult to obtain, and seemed to "disappear" before coming to the surface.

Deep Boring Northwest of Toyah.

Driller's Log

Log of Producers' Oil Company well, Huling-Ross No. 1, located in west half of Section 16, Block 59, Reeves county. Drillers: A. Wood, E. W. Dodge, W. A. Nance, J. R. Dodge. Began drilling upper 2350 feet of well on December 5, 1910; finished June 23, 1911; cable rig used. Hole caved badly at 160 feet, water at 735 feet; oil and gas showing at 840 feet, showing very little oil at 1855 feet, very strong gas at 1875 feet, oil showing in 15 feet of hard sand. Stuck bailer and tools in hole at 2205 feet. Well was dry. Began drilling deeper on March 26, 1911; drilled to 4100 feet, with cable rig; well still dry; finished August 7, 1914.

Upper part of well:		Lower part:	
284 feet	12½-inch casing.	337 feet	12½-inch casing.
754 feet	10-inch casing.	550 feet	10-inch casing.
878 feet	8-inch casing.	1070 feet	8-inch casing.
1226 feet	6¾-inch casing.	2105 feet	6¾-inch casing.
		Depth, in feet, Below surface.	
		From	To
Gypsum	.....	0	10
Gumbo	.....	10	220
Gypsum	.....	220	276
Water sand	.....	276	286
Gypsum	.....	286	340
Hard sand (water)	.....	340	390
Sand and gumbo	.....	390	420
Gumbo	.....	420	490
Soft white gumbo	.....	490	535
Sand, gumbo and rock	.....	535	550
Red clay	.....	550	620

Blue gumbo	620	670
Limestone	670	742
Sand	742	752
Red clay	752	757
Water sand	757	780
Blue gumbo	780	820
Crystallized gypsum	820	840
Water sand	840	860
Gumbo, limestone and gypsum	860	880
Gypsum and shale	880	900
Gypsum and limestone	900	930
Blue gumbo	930	960
Limestone, gumbo and gypsum	960	1030
Red bed (clay?)	1030	1060
Red bed and gypsum	1060	1100
Gypsum	1100	1200
Red bed and gypsum	1200	1260
Red bed, gypsum and shells	1260	1340
Gypsum and sand	1340	1650
Hard gypsum	1650	1680
Hard gypsum (white and black)	1680	1855
Gypsum, limestone and shale	1855	1875
Dark gypsum, shale and little sand	1875	2160
White gypsum	2160	2240
Sand and gypsum	2240	2335
Hard sand	2335	2350
Gypsum	2350	2695
Gypsum and lime mixed	2695	2725
Lime, gray	2725	2815
Gray lime	2815	2875
Gypsum	2875	2900
Lime and gypsum mixed	2900	3000
Dark gray lime	3000	3070
Sand and lime broken	3070	3082
Hard sand	3082	3130
Fine and soft sand	3130	3230
Black lime	3230	3235
Sand and lime mixed	3235	3315
Sand	3315	3445
Sand with trace of shale	3445	3455
Sand	3455	3500
Black lime	3500	3510
Sand	3510	3535
Lime	3535	3545
Lime and sand	3545	3575
Black lime	3575	3580
Sand	3580	3590
Gray lime	3590	3600
Black lime	3600	3615
Sand	3615	3616
Lime	3616	3695
Sand	3695	3700
Sand and lime	3700	3705
Sand and lime shells	3705	3715
Gray sand	3715	3730
Lime	3730	3745
Sand	3745	3760
Lime	3760	3790

Sand	3790	3805
Lime	3805	3830
Sandy lime.....	3830	3845
Lime	3845	3890
Sand	3890	3895
Sand and lime.....	3895	3923
Dark gray sand.....	3923	3970
Black lime	3970	3980
Sand and lime.....	3980	4000
Lime	4000	4040
Gray sand.....	4040	4055
Lime and sand.....	4055	4070
Sand	4070	4085
Lime, gray.....	4085	4100

Samples.

Description of samples from Huling-Ross No. 1 well:

	Depth, in feet, Below surface.	
	From	To
A piece of impure gray sandstone collected when well was shot at 1800 feet, and judged by a driller to have come from the depth of from 1400 to 1500 feet. This is a gray sandstone consisting of grains mostly from 1-16 to $\frac{1}{4}$ mm. in diameter.....	1400	1500
A piece of rock taken when this well was shot and judged by a driller to have come from near 1800 feet, is a very compact dark brownish gray dolomite cut by joints or crevices which are filled with anhydrite. It is indistinctly stratified. In thin section, vertical, it shows indistinct stratification marked by yellowish irregular streaks.....		1800
Light gray anhydrite containing small streaks and specks of dolomite. In one thin section an area of dolomite is cut by a small vein of anhydrite. The dolomite bodies are not sharply defined in outline		2000
Gray anhydrite containing some dolomite.....		2050
Gray anhydrite containing dolomite which occurs in yellow layers and irregular tracts in a thin section. On heating in closed tube drops of oil appeared...		2100
White granular anhydrite.....		2150
Thinly laminated gray anhydrite. Many of the cuttings are thin flakes, some parallel and some vertical to the lamination. Laminations are marked by the presence of yellowish dolomite.....		2200
Gray anhydrite		2250
Gray anhydrite. The larger pieces show lamination with darker and lighter layers. Oil was noted when heated in a closed tube.....		2300
Gray anhydrite. In thin section the larger pieces show laminations of yellow dolomitic material 4 mm. thick, alternating with transparent layers of anhydrite about 1.2 mm. in thickness. The dolomitic layers merge into the anhydrite on the sides and are crossed by many small veins filled with anhydrite, as if shrunk laterally.....		2350

Gray granular anhydrite showing laminations of darker and lighter layers, the darker containing more dolomite.....	2400
Granular anhydrite.....	2450
A thinly laminated gray rock consisting of granular anhydrite and carbonates, probably a mixture of limestone and dolomite.....	2500
Granular anhydrite. The larger pieces show lamination with alternate light and dark layers running at oblique angles to the longer diameter of some fragments.....	2550
Granular anhydrite. The larger pieces show light and dark laminations from 0.2 to 1 mm. in thickness. Bituminous fumes were given off, when heated in a closed tube.....	2600
Gray dolomite and anhydrite in intimate mixture. Bituminous fumes were given off when heated in a closed tube.....	2650
Gray, granular, laminated anhydrite containing some dolomite and apparently some shale.....	2700
Gray, granular anhydrite, containing some dolomitic material. Note on label says "Top of lime".....	2715
Mostly soft yellow dolomite, and some anhydrite....	2750
Gray, granular anhydrite, containing some calcareous matter. Label is marked "gas".....	2785
Gray, granular anhydrite, some gray limestone, and some yellow dolomite showing small, peculiar reliefs on the bedding planes. Considerable pyrite is present, partly incrusting surfaces on some fragments. The gray limestone is foraminiferal, containing <i>Textularia</i> (?) sp., <i>Nodosaria</i> , and many perforated fragments of tests, also thin fragments of <i>Ostracod</i> shells. An almost entire valve of small pelecypod was noted.....	2800
Gray anhydrite and dolomite.....	2850
Laminated gray anhydrite and some soft yellow dolomite in large fragments.....	2900
Laminated gray anhydrite and some soft yellow dolomite in large fragments.....	2950
Laminated gray anhydrite.....	3000
Black silt, a thinly laminated limestone with vertical cleavage, and a soft granular sandy gray dolomitic limestone. A vertical section of the laminated limestone shows that the layers are separated by sharply marked stylolitic joints which are filled with a black substance. Heated in a closed tube, the sample yields drops of oil and fumes of ammonia. In thin section the black silt is seen to contain much bituminous material and shows some minute broadly elliptic bodies filled with a transparent material. The silt or sand is mostly from $\frac{1}{4}$ to 1-16 mm. in diameter.....	3050
Fine, gray, silty quartz sand containing rare scales of mica.....	3100
Gray, fine-textured quartz sand, mostly less than one-eighth mm. in diameter.....	3150
Gray sandy silt and some dolomitic material.....	3200

Sandy dolomitic silt with some impregnating black bituminous material. Strong fumes of sulphur and bitumen given off, when heated in closed tube. When ignited the black shale sustains a flame....	3250
Gray, fine sand and some dolomitic rock.....	3300
White quartz sand from 1-16 to $\frac{1}{4}$ mm. in diameter	3400
Dark, almost black, greenish shale containing dolomitic material and sand. Yields fumes of bitumen, sulphur, and ammonia, when heated in closed tube	3450
Fine light gray quartz sand with some dolomitic material	3500
A sandy gray silt, micaceous and containing some dolomitic material.....	3550
Black sandy dolomitic silt, and gray fine sandy rock. Heated in closed tube it gives much oil.....	3600
Sandy dolomitic and silty rock. Some is gray, some black. Scales of mica noted. The black rock distills much oil. The texture of the rock is fine and close	3650
Gray sandstone of fine texture, impregnated with some dolomitic material.....	3700
Shaly, dolomitic, fine gray sandstone, containing some mica scales.....	3720
Sandy and shaly gray dolomite.....	3725
Dolomitic and shaly gray sandstone, slightly bituminous	3730
A black rock consisting of fine sand cemented by bituminous and dolomitic material. Distills very much oil.....	3735
Dolomitic and shaly sandstone, some gray, some black. The black contains much oil, the gray, much dolomite	3740
Gray, fine sand, cemented by dolomitic material....	3745
Gray rock, consisting of fine sand in a cement of dolomite	3750
Sandy material, part of which is in a cement of mainly dolomite, and part in a cement of mainly bitumen. Oil drops were noted when heated in a closed tube.	3755
Dark gray rock consisting of quartz grains in a cement partly composed of dolomite, but mostly of bituminous matter. Oil distilled off in a closed tube ..	3760
Dark gray rock consisting of quartz grains, some in a cement of dolomite, but mostly in a cement of bitumen. Oil distills off in a closed tube.....	3765
Dark gray rock containing quartz grains, cemented together mostly by bitumen, but also by some dolomitic material. Effervesces briskly. Oil distills off when heated in closed tube.....	3770
Black rock containing quartz grains cemented together with bitumen and some dolomite. Distills off oil in closed tube.....	3780
Dark gray rock containing quartz grains cemented together. Most of the cement is bitumen and forms a black mass, some is dolomite. Oil is distilled off when heated in closed tube.....	3785

Dark gray rock containing quartz grains cemented together with bitumen and dolomitic material. Oil distilled off when heated in a closed tube.....	3790
Gray rock containing quartz grains cemented together by more dolomite than bitumen. Oil distilled off when heated in a closed tube.....	3795
Gray silt cemented together with dolomite and a little bitumen. Bituminous fumes were given off when heated in closed tube.....	3800
Dark gray silt cemented together with dolomite and bitumen. Oil was distilled off when heated in a closed tube.....	3805
Black silt cemented together with bitumen and dolomite. Oil is distilled when heated in a closed tube.....	3810
Dark gray silt cemented with bitumen and dolomite. Oil was distilled off when heated in a closed tube..	3815
Black rock containing silt cemented together with bitumen and dolomite. Oil distilled off.....	3820
Dark gray silt cemented with bitumen and dolomite. Oil distilled off when heated in a closed tube. Pyrite and mica noted.....	3825
Fine yellow sand, and black silt cemented together with bitumen. Oil is distilled off when heated in a closed tube.....	3830
Gray and some black silt, cemented together by bitumen and dolomite. Oil is distilled off when heated	3835
Very dark gray silt cemented together with bitumen and dolomite. Oil is distilled off when heated in a closed tube.....	3840
Some dark and some light gray silt cemented together with bitumen and dolomite. Oil was distilled off when heated.....	3845
Yellowish gray sandy silt cemented together with dolomite and a little bitumen.....	3850
Gray silt, cemented together with dolomite and a small amount of bitumen. Bituminous fumes distilled out, when heated in a closed tube.....	3855
Sandstone cemented by dolomite. Bituminous fumes were given off when heated in a closed tube.....	3860
Black rock consisting of sandy silt cemented together with bitumen and a little dolomite. Oil was distilled off	3865
Black rock consisting of silt cemented together with bitumen and dolomite. Yields much oil when heated in a closed tube.....	3870
Almost black rock consisting of quartz grains cemented together with bitumen and some dolomite. Oil was distilled off when heated in a closed tube..	3875
Very dark gray rock consisting of sand and silt cemented with bitumen and dolomite. Oil was distilled off when heated in a closed tube.....	3880
Black rock consisting of sandy silt grains in a cement of bituminous and dolomitic material. Oil was distilled off in a closed tube.....	3885
Some gray and some black rock, consisting of quartz grains in a cement of bitumen and dolomite. Oil was distilled off when heated in a closed tube....	3890

Gray sandy silt in a cement of dolomite and some bitumen. Oil was distilled off when heated in a closed tube.....	3895
Light gray rock consisting of silt cemented together with dolomite and some bitumen. Oil was distilled off when heated in a closed tube. Mica noted.....	3900
Gray rock consisting of silt cemented together with dolomite and some bituminous matter. Oil fumes were given off when heated in a closed tube. Mica noted	3905
Gray rock consisting of silty sand slightly cemented with dolomite and some bitumen. Yields fumes of oil when heated in a closed tube.....	3910
Bluish gray rock consisting of silt in a scant cement of dolomite. A little mica was noticed. Sulphur and bituminous fumes were given off when heated in a closed tube.....	3915
Gray rock consisting of silt cemented together with a little dolomite. Some mica noted. Yields fumes of oil when heated in a closed tube.....	3920
Gray sandstone of fine silty texture containing a little dolomite and a few scales of mica. Yields oil fumes in a closed tube.....	3925
A gray silty fine sandstone containing a little dolomite. Mica was noted. Yields sulphur and bituminous fumes when heated in a closed tube....	3935
A gray sandstone of fine texture containing dolomite and some mica. Yields bituminous and sulphur fumes when heated in a closed tube.....	3940
Black rock of fine texture consisting of sandy silt cemented together with bitumen. Some mica was noted. Yields much oil when heated in a closed tube. Rock burned when heated in the flame....	3950
Black and dark gray rock consisting of sandy silt cemented together with bitumen and a little dolomite. Contains some mica. Yields oil when heated.....	3960
Dark gray rock consisting of silt cemented together with bitumen and some dolomite. Yields oil in a closed tube when heated.....	3965
Quartz sand, some grains of which are cemented tomented together with dolomite and some with bitumen and dolomite. Bituminous fumes were given off when heated.....	3975
Gray silty sandstone containing dolomite and a little mica. Yields bituminous fumes when heated in a closed tube.....	3970
Gray and black rock consisting of sandy silt cemented with bitumen and dolomite. Yields oil in a closed tube when heated.....	3985
Dark gray rock composed of sandy silt cemented with bitumen and dolomite. Yields oil when heated...	3990
Black rock of fine texture consisting of silt cemented with bitumen and dolomite. Yields oil when heated in a closed tube. Mica and pyrite noted. In thin section several imbedded pieces of thin shells, rounded concretionary (?) grains, spines, and a small Trochammina were noted.....	3995

A black rock consisting of calcareous silt impregnated with asphaltic material. Pyrite noted. Yields oil and burns with a flame. Pieces of thin small shells noted, one entire ostracod shell seen, one Endothyra and fragments of spines. In thin section the rock is seen to consist of angular quartz fragments imbedded in a calcareous and asphaltic matrix, in which appear fragments of spines, shells, Trochammina incerta d'Orbigny, and thin valves of ostracods	4005
Dark gray rock consisting of sandy silt in a cement of bitumen and dolomite. Yields oil when heated.	4020
Dark and light gray rock consisting of silt in a cement of dolomite and in bitumen. A few flakes of mica noted. Yields oil in a closed tube when heated	4025
Gray rock consisting of sandy silt in a cement of dolomite and some bitumen. Yields oil in a closed tube	4030
Dark and light gray sandy silt in a cement of dolomite. Bituminous fumes were given off when heated	4035
Gray rock containing sandy silt in a cement of dolomite and bitumen. Bituminous fumes were given off when heated.....	4040
Dark gray and light gray sandstone containing dolomite. Bituminous fumes were given off when heated	4045
Fine grained white sand and dolomitic material. Bituminous fumes were given off when heated.....	4055
Dark gray sandy silt in a cement of bitumen and dolomite. Yields oil when heated.....	4065
Dark gray rock of fine texture composed of silt in a cement of bitumen and dolomite. Yields oil when heated. In thin section, the quartz grains are seen to be angular, cross sections of spines or spicules were noted, and a flat Ammodiscus.....	4115

Note.

Twenty-three samples, representing the rocks penetrated from 2000 to 3000 feet below the surface, consist of anhydrite, in the main, intimately associated with more or less dolomite, and having mostly a thinly laminated structure, such as is seen in parts of the Guadalupian formation. Some fragments showed that this rock has in places been brecciated.

At 2700 there is some nearly pure dolomite. Near 2800 there is a gray limestone containing some foraminifera and fragments of small shells and other fossils. In this part of the section the rock is otherwise uniform in character, being anhydrite and dolomite. Below this depth the samples from 3050 to 4115 feet consist of a rock which may be described as dolomite containing more or less fine sand, silt and clayey material. The range of variation in the composition of this rock is from nearly pure dolomite containing only a small amount of siliceous material to pure sand, as at 3100, 3150, 3400, and 3500 feet below the surface. At various depths, this rock has been impregnated with much bituminous material, so as to be black. This condition was noted at 3050, 3250, 3450, 3600, 3735, 3755-3785, 3805-3820, 3840, 3860-3885,

3950, 3990-4000, 4065, and 4115 feet, making a thickness of nearly 100 feet of black asphaltic rock. Much of the other sandy dolomite is to a less degree impregnated with hydrocarbons, so that nearly all the samples from this part of the well will yield bituminous fumes and even drops of oil when heated in a closed tube.

A mixed sample of this black rock taken from five different depths has been distilled to determine the hydrocarbon content. It was found to contain 14.2 per cent. of volatile combustible hydrocarbons. This includes an amount of oil equivalent to 2.4 gallons per ton of the rock.

The uppermost several hundred feet of this boring, possibly a thousand feet, are believed to be the Comanchean. The strata from 1030 to 1315 feet below the surface is probably to be referred to the Permian redbeus. The 2785 feet of strata below this are all believed to be in the Delaware formation, and are probably to be correlated with the Dolomite beds in the Spur well, Dickens county.

DISCUSSION OF THE DATA.

Indications of Desiccation.

The existence of extensive salt beds is conclusive proof of general desiccation in the redbed sea. For the precipitation of potash salts in any natural water, extreme desiccation is required. The geographical conditions necessary for such concentration of sea water is the separation of smaller basins from the main body of the sea. It is not at all likely that the concentration in the open sea has ever in the past approached a condition near the limit of saturation for potash salts. In the finding of natural potash salts, there is, therefore, a presumption that their location is in an ancient isolated basin.

Indications of An Isolated Basin.

There are several other circumstances which suggest that the Staked Plains are located in a place where an isolated basin existed when the salt beds were formed. Several circumstances indicate, at any rate, that the west half of the Panhandle is near the central belt of a geosyncline whose axis runs nearly north and south.

A mild suggestion of the existence of such a geosyncline (a belt where the earth's exterior has been relatively settling more, or elevated less, than in the surrounding country, and where possibly this condition of secular relative movement has long existed and is still to some extent maintained) is to be found in the great topographic feature known as the Llano

Estacado. This is a level plain, from 100 to 150 miles wide, into which the drainage lines on all sides have made slow progress as compared with other regions farther north, similarly situated with regard to the larger features of our continent. Erosion on the Llano Estacado has, during a part of the Pleistocene and perhaps also Tertiary time, been at a standstill. This condition has permitted the accumulation of a considerable thickness of Pleistocene, and possibly some Tertiary, material, while the surrounding land has been eroded. The suggestion is that a contributive cause to this condition may have been that the Llano Estacado has not been lately elevated as rapidly as the surrounding parts of the Great Plains. The suggestion is given for what it may be worth. Much importance can not be assigned to it, owing to our lack of knowledge of the relative value of other factors, which must also be taken into consideration in the interpretation of the physiographic features of the plains.

Conclusive evidence of the existence of a geosyncline in this belt is, however, not wanting. All geologists who have studied the region on either side of the Llano Estacado, east or west, have found the general dip in the adjoining country to be in toward the Plains. East of the Staked Plains, the dip is to the west; and on the west side, the dip is to the east. The west dip on the east side is extensive, and quite high for its extent. Along some lines, in places, it amounts to at least thirty feet per mile, and it continues for nearly two hundred miles. Lower and lower strata come up to the surface in this direction. On the west side of the Staked Plains, the dip is known to be to the east, away from the mountains in New Mexico. Cummins noted that the dip decreases as the plains are approached from this direction, and he was probably the first to note that "the Staked Plains may be said to be in a Permian basin."

In the well data already presented, the only clear evidence of the existence of this geosyncline at the south is found in the fact that in the Huling-Ross well, the redbeds, if present, do not extend deeper down than to 1615 feet above sea-level; while in the Buena Vista well, they certainly continue down to 985 feet above the sea-level.

In the northern wells, the basin structure is less conspicuous. Correlations of the well sections are somewhat uncertain, owing to the variability of the redbed deposits. For the major divisions of the well sections, the Pleistocene, and possibly Tertiary, the Triassic, the Permian redbeds, and the Permian dolomites, some correlations are given in each case in the notes on these borings. It does not seem possible to more than surmise what any of the equivalencies are between different members within the redbeds. There seem, however, to be two zones of salt beds. In the Childress boring, only one of these zones is represented; no doubt the lower. This begins at a depth of 800 feet and may be said to extend down to the bottom of the more shallow boring, No. 3 of the boring at Childress. In the McLean boring, salt was noted at 625, 845, and at 1250 feet. Another salt was passed through at 1650 feet. In the Miller well there were some salt beds at from 940 to 1170 feet and another series of heavy salt beds from 1390 to 2480 feet. In the Boden boring the salt beds seem to merge into one continuous series of close-lying salt beds, extending from 640 to 1460 feet, and beginning again at 1690 feet. In the Snyder boring, several salt beds occurred between 655 and 1020 feet. These probably correspond to the lower salt beds farther north. A still lower group of smaller salt beds was recorded at depths from 1570 to 1940 feet. In the Post boring, the curb of which is about 600 feet above that of the Scoggin boring, the salt reported between 1300 and 1440 feet apparently represents the upper group in the Snyder boring. The salt in the Scoggin and Justiceburg borings is to be referred to the upper of these groups. In the Spur boring there was only one group of well developed salt beds, from 570 to 1174 feet.

Small reliance can, however, be placed on a correlation of these groups between the different explorations, except for borings located near together. It appears that in the Adrian boring, salt deposition suffered but little interruption throughout the making of 1700 feet of sediments. It is to be observed, also, that the upper group of salt beds seems best developed in the Boden boring, and the lower group is better developed in the Miller boring. As already stated, the two groups seem to coalesce, or run together in the Boden boring, and this may

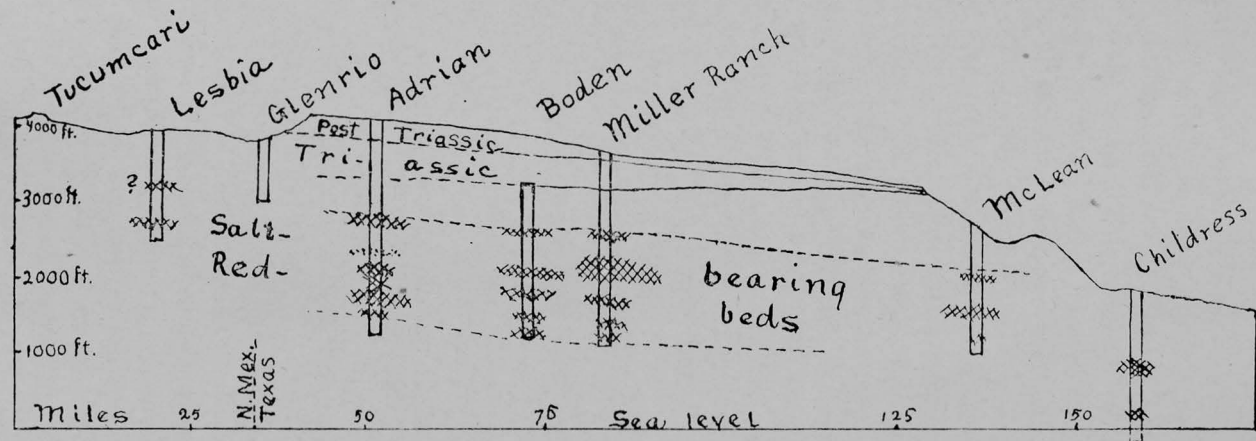
be said also to a lesser extent to be the case in the Miller boring. Such a condition would be most likely to result near the center of a basin undergoing gradual desiccation. It is possible that the uppermost salt beds in the Boden and Miller borings are not represented in the borings farther south. But with the few records in hand, a correlation of the salt bed groups in the northern explorations with those in the region farther south, is hardly warranted.

Tilting of the Basin.

Another circumstance that obscures the view of the basin structure in the well sections in the north, is the fact that the geosyncline in this region is itself tilted to the east. As we proceed westward from Childress, we go up a high gradient; from 1877 feet above sea-level at this place, to 4100 feet at Adrian. The dip between these two points appears to be easterly, everywhere. But east of Amarillo, this dip is probably smaller than to the west of Glenrio. Referred to the present land surface, the Triassic, at any rate, plainly descends as we go west from Childress until we come to Amarillo. Westward from the west boundary of the State, this formation is believed to run more nearly parallel with the general slope of the surface of the land. The geosynclinal structure is manifest mainly in a difference in the rate of the east dip of this formation. The north to south axis of the basin is, then, located where the change in this rate is greatest. This change is evidently quite gradual. With the data from borings now at hand, it appears that the Adrian, the Boden, and the Miller borings are nearer the center of this basin than any of the other explorations reported.

It is evident, as already stated, that the Permian basin itself has been tilted to the east. This feature of the structure is further elucidated in Figures 3 and 4.

The present writer does not know if Cummins held the view that the Permian basin was a basin in the Permian age, or if he had in mind a solely structural basin, due to a synclinal flexure formed at some later time than the Permian. There is some evidence in the drill records that the Staked Plains region was a basin in the Permian sea, and that this geosyncline



Bull. 17-1915. Fig. 4.

is like many others, in that it is situated in a place where the earth's exterior has suffered, on the whole, a slight downward flexing for a long period; dating, in this case, perhaps, as far back as before the Permian age itself. This evidence is in the data we possess on the relative size of the salt beds at different points. It may be taken for granted that the salt beds are thickest where the sea in which they formed was deepest. It may also be assumed that the several salt beds represent the total salt deposits in one major basin. The latter assumption may or may not be entirely true. Another assumption whose validity is not quite certain, we may also make: that the wells reaching 1800 feet, or a little more, have penetrated the greater part of the salt beds. If we then sum up the total thickness of the salt beds in the explorations which are on the east of the axis of the basin, we find that salt deposition has been notably greater near the supposed center of the basin than farther east. This is suggested by the following table:

Table showing the estimated combined thickness, in feet, of salt beds penetrated by some borings in the Panhandle.

Names of Borings:	Adrian.	Boden.	Miller.	O'Dell.	Childress.
Explored thickness of salt beds-----	900*	579**	897	400***	315

*Partly estimated.

**Fifty feet in this amount is estimated to have been penetrated in the lowermost 200 feet, which the log describes as being "red sandy clay with occasionally thin strata of salt"

***Estimated.

This westward thickening of the salt beds is so far evident only in that part of the Staked Plains which is in the Panhandle. For the south extension of the Plains, no records of any borings near the central axis of the basin have yet been obtained. The Buena Vista and the Upland borings both went below the depth of the records secured, and from conversations the writer had with the drillers, his impression was that at both places more salt had been penetrated than the records indicate. The drillers at each of these places stated that from much of the holes in the red clays and sands, there had been very little silt or sand in the water carrying the returns. The returns had seemed to disappear.

The form, extent and direction of the Permian basin of the Plains can be conjectured mainly only from what is known

of the physiography and the general geological structure in the surrounding country and in the Plains country itself. The longer axis of the basin evidently extends in a general direction from north and south. It probably lies in a belt reaching from near the southwest quarter of the Panhandle at the north, to near Andrews county at the south. The axis of the Marathon anticline, already rising in Permian times, intersects the axis of the Plains basin not far to the south of the Pecos river. The old basin certainly did not extend south of this axis. Its north limit is less evident. From the southwest part of the Panhandle it may have extended northeast, north, or northwest; or perhaps the barrier separating this basin from the northern waters in the redbed sea lay near this region. At any rate, it is recognized that this part of our present continent was near the southwest limits of the Permian sea, which here made a wide detour to the south.* It is in just such an angle of the sea that the geographical conditions would exist, which might result in the isolation of a minor basin where desiccation might be complete, or might reach saturation for potash salts.

The Finding of Potash-bearing Salt.

In some of the cuttings coming from the Boden boring, I found small fragments of salt having a salmon red color. These were submitted for analysis to Dr. Phillips, the Director of the Bureau. The quantity was small, so that the result is to be considered approximate only. The analysis is, however, no doubt substantially correct. This "red salt" contained 9.23 per cent. potash (K_2O) of the soluble portion. It contained very little insoluble material. The rock salt from which these red fragments were picked, gave only 0.99 per cent. of potash (K_2O). After these analyses had been made I looked for like red salt in the rock salt obtained from the Miller boring at from 1500 to 1700 feet below the surface. A small quantity was found also here, and this material showed 6.14 per cent. of potash (K_2O) in the soluble portion. The quantity used in this analysis was likewise very small, and was obtained from cuttings which contained much insoluble material, mostly

*Compare Paleogeography of North America, Charles Schuchert, Bull. Geol. Soc. Am., Vol. 20, Plate 85.

anhydrite. Two additional small lots of red salt were later picked from the cuttings marked as from 1500 to 1700 feet below the surface from the Miller well. These gave, respectively, 1.72 and 2.79 per cent. of potash (K_2O) of the soluble portion. The red fragments in these last lots were not red all through, but consisted in part of colorless salt.

In order to obtain more material, a visit was afterward made to the parties from whom these samples had been obtained. Seven samples from known depths in the Miller boring were secured. Some of these were duplicates of the samples already examined. In addition to these samples, ten lots of rock salt mixed with other cuttings were collected from the dump at the Boden boring and nine similar samples from the dump at the Miller boring. At the latter place, the dump had been exposed to rains for a year, and to overflows. At Boden, the dump had been exposed to the weather for less than a year, and there had been no overflow, as the boring is on ground lying above high water.

One sample of rock salt coming from between 875 and 925 feet below the surface in the Boden boring gave 1.16 per cent. of potash (K_2O) in the solubles. Other parts of this salt gave 0.99, 0.45, 0.94 and 0.98 per cent, respectively. In at least one of these lots, minute fragments of red salt were noted. The salt giving 0.45 per cent. was imbedded in anhydrite rock. Salt from between 1240 and 1290 feet below the surface gave 0.43 per cent. Some salt from 1290 to 1460 feet gave 0.70 per cent. Only one small lot of grains of red salt was secured from the new samples obtained from known depths in this boring, and most of the fragments making this picked lot contained mixtures of red and colorless salt. On analysis this picked lot showed 2.07 per cent. of potash (K_2O) of the soluble portion.

Two analyses of some salt taken from below 1300 feet in the Miller boring contained, respectively, 0.62 and 0.91 per cent. of potash (K_2O). A sample of the salt imbedded in anhydrite from below 1700 feet was found to contain 10.50 per cent. of potash (K_2O). This salt had no unusual color.

Some salt samples were taken from the dump of these borings. A large part of the dump at each place consists of fairly clean cuttings of salt. The material which lies uppermost was

separately sampled in a place where it was known to have come from the deeper part of the boring at the Miller Ranch. At Boden different parts of the dump were identified, by a gentleman who had closely watched the progress of the drilling, as representing the lower, the middle and the upper part of the boring.

Undoubted red salt was not found in any of the samples from the dump at the Miller boring. Some fragments showed a rusty red color, probably due to the presence of some very fine red silt or to rust derived from fragments of the steel of the bit. The percentages of potash (K_2O) in nine samples of salt from the dump of this boring vary from 0.31 to 0.64 and average 0.45. In the dump from the Boden boring a small lot of fragments containing undoubted red salt were found. These gave 1.74 per cent. of potash (K_2O). Some salt containing doubtful red material gave 0.71 per cent. Eight other samples contained from 0.25 to 0.68 per cent., averaging 0.44 per cent., practically the same amount as in the salt from the dump at the Miller boring. It is believed that this figure (0.44%) approximates the average potash contents of the main salt beds in the region.

A visit was also made to Adrian, where a deep hole was bored several years ago. When this boring was made, a number of samples of cuttings were taken and preserved in bottles. One of these bottles was found. It had been preserved by Mr. O. Olson, a farmer living in the vicinity. This bottle contained nine layers of different cuttings, representing, no doubt, separate strata of rock salt, anhydrite, and some shale, each about a half-inch thick in the bottle. The depth where this lot was taken was not known. Evidently it represented some salt beds, no doubt below the depth of 700 feet. An analysis of a mixed sample for the lot gave 0.31 per cent. of potash (K_2O). By diligent search a single fragment of red salt was found in this salt, less than a millimeter in diameter, and too small for analysis. All analyses made for this report are presented, for more ready reference, in the following tables:

Table I.

Contents of potash (K_2O) in percentages of soluble portion of rock salt from the Boden boring, Potter County.

Number of Analysis.	Nature and condition of sample.	Depth in feet below surface, or inferred part of the boring.	K_2O in percentage of soluble portion.
2193	Rock salt.....	875-925	0.99
2257	Rock salt.....	875-925	1.16
2258	Crystals of rock salt in anhydrite.....	875-925	0.45
2280	Rock salt containing some red fragments.....	875-925	0.94
2274	Rock salt.....	875-925	0.98
2282	Rock salt.....	1290-1460	0.70
2283	Rock salt.....	1290-1460	0.43
2235	Rock salt, in part red, from dump.....	Upper part	0.71
2273	Rock salt, from dump.....	Upper part	0.31
2234	Rock salt, from dump.....	Upper part	0.68
2275	Rock salt, from dump.....	Upper part	0.25
2276	Rock salt, from dump.....	Middle part?	0.43
2284	Rock salt, from dump.....	Lower part	0.26
2278	Rock salt, from dump.....	Lower part	0.49
2285	Rock salt, from dump.....	Lower part	0.68
2279	Rock salt, in a matrix of anhydrite.....	Not known	0.43

Table II.

Contents of potash (K_2O) in percentages of soluble portion of small fragments of red or pink salt (carnallite?) picked from samples of rock salt from the Boden boring, Potter County.

Number of Analysis.	Nature and condition of sample.	Depth in feet below surface, or inferred part of the boring.	K_2O in percentage of soluble portion.
2281	Some colorless salt present.....	870-930	2.07
2193	All red salt.....	875-925	9.23
2236	Taken from dump, some colorless salt present.....	Middle	1.74

Table III.

Contents of potash (K_2O) in percentages of the soluble portion of rock salt from the Miller boring, Randall County.

Number of Analysis.	Nature and condition of sample.	Depth in feet below surface, or inferred part of the boring.	K_2O in percentage of soluble portion.
2293	Cuttings of rock salt, no color.....	1300+	0.62
2295	Cuttings of rock salt, some yellowish.....	1300+	0.91
2296	Cuttings taken on dump.....	Middle?	0.37
2297	Cuttings taken on dump, some reddish fragments.....	Middle?	0.37
2294	Cuttings taken on dump, some reddish fragments present.....	Lower	0.33
2287	Cuttings taken on dump.....	Lower	0.31
2282	Cuttings taken on dump.....	Lower	0.64
2289	Efflorescent salt on surface of dump.....	Unknown	0.49
2298	Cuttings taken on dump.....	Unknown	0.47
2291	Cuttings taken on dump, much shale present.....	Unknown	0.49
2288	Cuttings from dump, (some red salt present?).....	Unknown	0.56

Table IV.

Contents of potash (K_2O) in percentages of soluble portion of small fragments of red or pink salt (carnallite) picked from samples of rock salt, and of one sample of colorless salt contained in anhydrite from the Miller boring, Randall County.

Number of Analysis.	Nature and condition of sample.	Depth in feet below surface, or inferred part of the boring.	K_2O in percentage of soluble portion.
2215	Picked red salt fragments.....	1500-1700	6.14
2220	Picked fragments containing some red salt.....	1700-2100	1.72
2216	Picked fragments containing some red salt.....	1700-2100	2.79
2230	Colorless rock salt in anhydrite.....	1700+	10.50

Significance of the Find.

It is to be noted that all samples of salt from known depths in the Boden boring containing more than 0.70 per cent. of potash (K_2O) are from somewhere between 870 and 930 feet below the surface. The red salt from the dump representing the middle part of the well may have come from this depth also. The percentages of potash noted in salt from this depth are as follows: 0.94, 0.98, 0.99, 1.74, 2.07, 9.23.

It will also be noted that the red salt containing the greatest percentage of potash in the Miller boring comes from between 1500 and 1700 feet below the surface. The significance of these two occurrences becomes apparent when we find that the formations lie about 500 feet deeper under the surface at the Miller ranch than at Boden. Before entering the formation lying at the surface at Boden, some 500 feet of overlying material had to be penetrated at the Miller ranch. It is evident that red salt occurs at the same formational horizon in the two explorations. It all comes from the upper part of the second salt beds. The red salt found in the salt from 1700 to 2100 feet in the Miller boring may, to be sure, belong higher up, but this is unlikely. There may or may not be a corresponding lower potash bearing salt in the Boden boring. Observations on this point are wanting.

In the Miller boring a colorless salt containing 10.50 per cent. of potash (K_2O) is found in an anhydrite rock below the depth of 1700 feet, its exact position being unknown. The association of the two precipitation products of salt and anhy-

drite suggests that the potash may have come from the upper part of a salt bed, close to an overlying bed of anhydrite.

One very significant feature of the occurrence of the red potash-bearing salt is that it is found near or in the upper part of the principal salt beds explored. Six hundred feet of salt underlies the red potash-bearing salt in the Miller boring and five hundred feet underlies the same material in the Boden boring. This circumstance suggests that the deposition of potash was preceded by a long period of progressive concentration of the sea water, at the end of which the point of saturation for potash salts was reached, and these salts, also, began to separate out from the brine in the sea. It seems very unlikely that this condition should have been reached at the same time in two places thirty miles apart—this being the distance between the Boden and the Miller borings—without resulting in the deposition somewhere of considerable quantities of potash salts. With evidence that saturation for potash salts was attained in two places, and perhaps in three (Adrian), so far apart, this condition may be presumed to have been quite general.

Mineral Nature of the "Red Salt."

It is to be regretted that enough of the "red salt" was not secured for determining its mineral nature. The fact that it contained, in one case, as much as 9.23 per cent. of K_2O , and that it differs in color from the other salt with which it is mingled, suggests that it is a real mineral such as carnallite, or polyhalite. In the case of all the analyses containing a percentage of potash notably higher than most of the rock salt, this percentage evidently increases with the quantity of the "red salt" present, excepting the case of the colorless salt found in anhydrite below 1700 feet in the Miller boring. A mineralogical determination of this colorless salt as well as of the "red salt" must await the procuring of more material. In the meantime, the present writer is inclined to the belief that we have in this instance a natural mineral containing potash. So far as the present writer is aware, the occurrence of natural potash salts in association with rock salt in the Permian red-beds has not before been observed, although the salt beds in

this formation have been quite extensively explored all the way from Kansas and across Oklahoma to southwest Texas.

Prospecting for Potash.

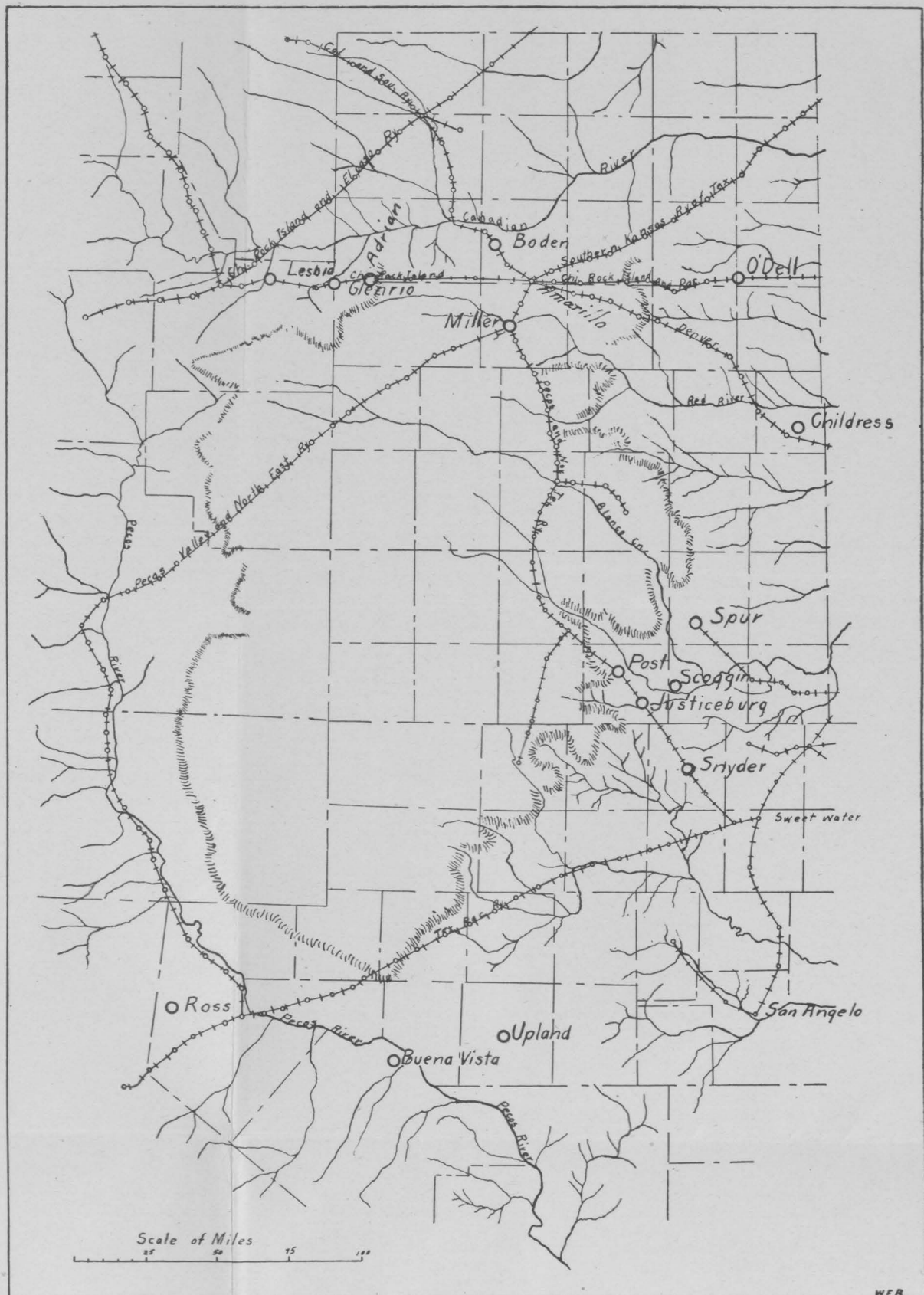
The finding of potash-bearing salt in the Boden, the Miller, and also, as believed, in the Adrian boring, was a fortuitous incident attendant on the making of some tests for oil or potable waters. Had potash been looked for at the time these explorations were made, we would no doubt now have much more definite information on the quantity of potash in the salt beds of the Plains. We are now limited to qualitative knowledge only. From the few samples taken—four from a 2600-foot hole, a half-hundred mostly from the barren beds in a 2000-foot hole, and nine samples from a 2825-foot hole—no estimate on the quantity of existing potash deposits can at all be made. One of the samples containing the potash is labelled as representing fifty feet of salt. It no doubt was collected from a single bucket and represents, at most, some five feet of the bed. What there was in the other forty-five feet, we do not know. Do the fragments of "red salt" in the samples from 825 to 925 feet in the Boden boring represent small segregations in the five feet of salt from which they probably come, or do they represent a larger deposit of such material passed through somewhere in the other forty-five feet of this salt bed? The tendency of potash is to diffuse. The latter supposition seems therefor the more plausible. But we do not know which may be the case.

Everything considered, the present writer believes that the problematic existence of utilizable potash in association with the Permian salt beds in the southwest is, by these finds, rendered sufficiently probable to warrant the beginning of explorations to settle the question of its presence or absence. From the evidence now in hand it would appear most profitable, perhaps, to make the first test in the vicinity of the localities where potash salts have already been discovered. The data presented show that extensive salt beds underlie not only the greater part of the Panhandle, but that they extend south to Upton county and west into New Mexico. Where in this extensive territory the Permian waters were most effectively

isolated from the main body of the ancient sea and most nearly, or wholly desiccated, can not well be made out by any examination of the superficial features of the region, except so far as it may be possible to make conjectures on the basis of the general structure as already indicated and on the basis of the nature of the sediments themselves as revealed by the drill. Such conjectures as it may be possible to make will lack the definiteness regarding localities that actual drilling tests will give. Leaving the region of the three wells already known to contain some potash salts, the territory which appears from our present knowledge to give most promise is along the supposed axis of the basin, southward and a little westward from Boden, the Miller Ranch, and Adrian.

From the explorations already made, it is evident that tests should extend to the greatest depth at which it may be considered profitable to work, say 2000 feet. The "red salt" horizon in the Miller and the Boden borings will lie, it is believed, over most of the territory indicated, between 2000 and 2400 feet above sea-level, or from 800 to 1700 feet below the surface.

Successful prospecting will necessitate the employment of drillers experienced in the coring of salt, and of the services of competent technical help to watch and determine the results as they appear.



Bull. 17-1915. Fig. 1.

Huling-Ross No. 1

Buna Vista

Upland

Snyder

Justiceburg

Scoggin

Post

Spur

Vertical Scale
Feet

3000

2500

2000

1500

1000

500

Sea level

500

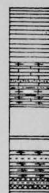
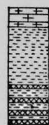
1000

1500

2000

2300

Potash



Lesbia New Mexico

Glentia

Adrian Oil and Gas Co

Boden

Miller Ranch

McLean

Childress

Vertical Scale
Feet

